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AN EXPERIMENTAL INVESTIGATION OF THE PHARMACOLOGICAL ACTION OF NITROUS OXID.*

DENNIS E. JACKSON, PH.D., M.D.
Associate Professor of Pharmacology, Washington University, Medical School.
ST. LOUIS, MO.

In the early days nitrous oxid was administered pure or almost pure, air being verey generally excluded. This led to the production of asphyxia after a very brief period and thus the duration of the anesthesia was necessarily short. At a later period it was appreciated that a certain admixture of air with the gas was feasible and even often improved the character and extended the duration of the anesthesia. In 1868 E. Andrews of Chicago first used pure oxygen with nitrous oxid. This was a great advancement, which, although not generally appreciated at that time, has now come to be fully recognized as indispensable in the scientific administration of nitrous oxid.

*Read by proxy during the second annual meeting of the Interstate Association of Anesthetists in Louisville, Ky., July 26-27, 1916.

Some months ago I devised a closed method for the administration of nitrous oxid and other anesthetics in conjunction with oxygen. I have used a number of different types of apparatus in connection with this method one of which has been described in a former publication.[1, 2] My chief object in the present article is to discuss certain features of the pharmacological action of nitrous oxid as studied by this method. No morphin, scopolamin or other hypnotic has been used in any of the experiments herein reported.

I may refer briefly to an improved form of apparatus which I have used in these experiments (Fig. 1). A rotary pump of less capacity than that used in the device previously described is attached to a very much smaller and more compact frame. The chief object in this has been to simplify the apparatus and to reduce its size and weight. A number of valves, tubes and accessories shown in the illustration have been found by experience to be unnecessary, but in the experimental development of the device they were included as precautionary measures. The apparatus carries only two tanks.

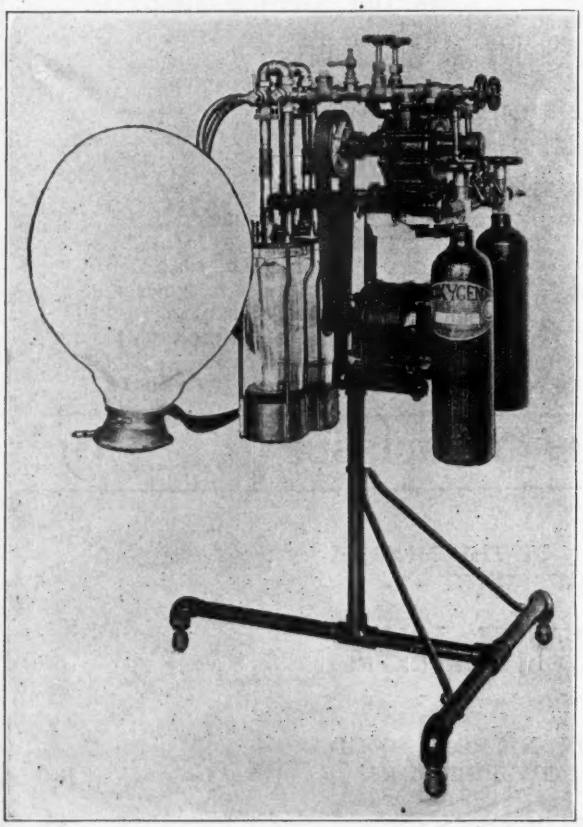

Fig. 1. Nitrous oxid apparatus with large bag as used for experimental purposes. (For discussion, see text.)

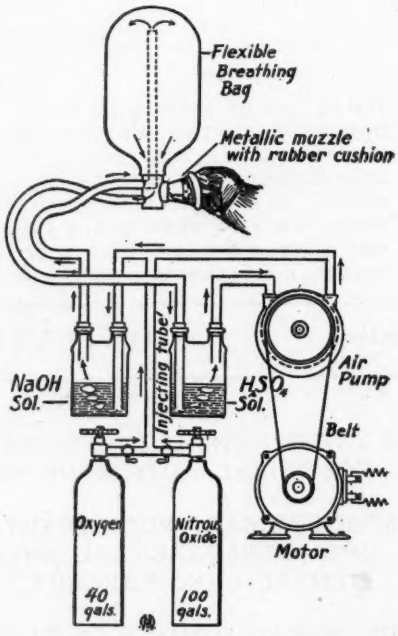

Fig. 2 Schematic diagram to explain the plan of construction of the apparatus shown in Fig. 1. The motor turns the rotary air pump which keeps the air (or gas and oxygen) circulating. (For discussion, see text.)

one for oxygen and one for nitrous oxid, for experience has shown that since tanks need to be renewed only at considerable intervals, and, if the breathing bag be filled moderately full at the moment when either tank becomes exhausted there will be ample time to remove the empty tank and replace it by a new one before a fresh supply of the gas (generally oxygen, of course) is required. Realizing the great value of simplicity and lightness in any form of apparatus intended for constant use, I have spent much time and energy in trying to produce as simple a device as possible. It is perfectly evident that the apparatus here shown is much more complicated than it need be, but for the benefit of others who may be interested in the subject of nitrous oxid anesthesia, I have thought it worth while to include here an illustration of the apparatus with which much of the work discussed below has been carried out. For a detailed description of the general principles on which the device is operated I must refer the reader to the article indicated above. By further reference to the diagram shown in Fig. 2 it will be seen that by means of a motor and a rotary air pump, air or other gaseous or volatile substances (chiefly nitrous oxid and oxygen so far as the present article is concerned) are kept circulating within a closed system of tubes and vessels, and through a breathing bag into and out of which the animal breathes.

The vessels are two in number and consist of glass jars, the one containing sulphuric acid which serves to sterilize, dry and warm the air (or gases) which are washed through the acid, while the other jar contains sodium hydrate solution through which the air or gases, including the exhaled CO_2 from the patient are washed. The CO_2 is immediately absorbed by the sodium hydrate forming sodium carbonate and water according to the following equation:

$$2\,Na\,OH + CO_2 = Na_2\,CO_3 + H_2O.$$

The sodium carbonate being a soluble salt of course remains in solution (together with the H_2O formed) in the jar, the CO_2 being thus removed from the air (or nitrous oxid and oxygen) which the animal breathes. During this process the oxygen is consumed (250 to 300 cc. per minute for an adult man at rest) by the animal or patient. More oxygen is injected into the system from time to time in just such quantities as the animal actually consumes. The nitrous oxid, being a stable gas, is not broken down at all either by the animal or by the acid or sodium hydrate. Consequently there need be but little waste of the N_2O and only a small amount (experimentally I have estimated that from 1½ to 3 gallons will be necessary for a man weighing 160 pounds) is required to saturate the blood sufficiently to produce anesthesia. When a given amount of N_2O is injected into the closed system and breathing bag, the animal, whose lungs virtually form a part of the closed system, will at once begin to absorb N_2O into its blood from the pulmonary alveolar walls. This absorption goes on until an equilibrium in the quantity of N_2O contained in the animal's blood and tissues on the one side and that contained in the breathing bag and tubes on the other is established. It is important, however, to remember in this connection that the affinity of the blood and presumably of the central nervous system is greater for N_2O than is the affinity of water for N_2O. So far as is known at present N_2O does not form any special chemical combination with the blood or other tissues of the body. It is apparently held in solution in the blood and tissues in the same way as any other indifferent gas dissolves in a liquid, i.e., in direct proportion to the partial pressure exerted by the gas on the liquid. The lipoid content of the blood and central nervous system is generally considered to account for the increased solubility of the gas in these tissues over that in water.

The breathing bag and face-piece shown in Fig. 1 are also modified considerably from that which I first used. The bag shown here I have found well adapted for experimental observations. It is chiefly from this standpoint that I want to discuss the action of nitrous oxid in this article. This bag holds three gallons, but the sides of the bag are flat and when not in use fall together as the air or gas passes out. When in use only about one or two gallons of air or gas need be injected into the bag and this permits the subject to have a full and free opportunity to breathe in any way he pleases. It is desirable that no excess pressure, as from an overfilled bag, be introduced to embarrass the breathing of the subject. The excess amount of work which may thus be easily thrown on the respiratory apparatus in the course of an hour may be astounding, as a brief mathematical calculation will readily show. And the problem is still further complicated both directly and indirectly by the embarrassment to the heart and lung circulation which the amount and peculiar application of this excess work involves. A further feature to be noted in the face-piece is the large opening, about three and one-half inches in diameter, which connects the bag to the air cushion resting on the face. Thus the subject breathes almost directly into the large flexible bag and obstruction of the respiration is reduced to a minimum. While this bag and face-

piece serve very well for experimental observations, there are certain objections which may be made to them from a practical standpoint. The first of these is the difficulty of making an air-tight contact between the subject's face and the rubber cushion on the face-piece. The second is the inconvenience of having the large bag near the patient's head. At present, however, I wish to avoid any extensive discussion of the clinical side of this subject.

THE GASES INVOLVED IN NITROUS OXID ANETHESIA

The pharmacological relations of at least four gases must always be considered in nitrous oxid anesthesia. These are N_2O, oxygen, CO_2, and nitrogen. And it may be worth while to remember that a small amount of argon, neon, crypton and xenon are also present. Ordinarily these gases are supposed to be inactive in the animal organism, but under the peculiar conditions established in the gaseous content of the body under nitrous oxid anesthesia, I am inclined to believe that the presence of these substances, at least at the beginning of the anesthesia, should not be entirely forgotten.

It should be emphasized that the method which I have here used permits investigation of peculiar gaseous relationships which no other device heretofore employed for this purpose could well reveal. For by this method the supply of the four gases (N_2O, CO_2, N, and O) concerned in the animal's respiration may be separately and independently controlled. The CO_2, of course, is eliminated by the animal, but it may be allowed to accumulate in the breathing bag for experimental purposes and its relative action in combination with the other gases thus studied. The relative effects of CO_2 and O in ordinary forms of breathing and in asphyxia have been thoroughly studied by numerous investigators.[3] When, however, nitrous oxid is introduced, the conditions are very materially changed and only a small amount of work has been done on this phase of the problem.

It was supposed by Sir Humphrey Davy that nitrous oxid was decomposed in the body which thus became flooded with an excess of oxygen, which was promptly changed to carbon dioxid. This carbon dioxid then acted as a depressant and caused the anesthesia. It was later shown that nitrous oxid was not thus broken down but was excreted by the lungs in the same form as that in which it had been absorbed. The theory then became prevalent that nitrous oxid acted solely by excluding oxygen from the tissues and that its action was chiefly a matter of asphyxia. That asphyxia may, and in practice certainly does often play a considerable part during the production of the anesthesia, no one at present doubts. But it has been thoroughly established that nitrous oxid possesses distinct specific depressant powers of its own on the central nervous system. In 1897 Kemp[4] published a series of observations on the gaseous content of the blood during nitrous oxid anesthesia. He drew off blood from the femoral artery of dogs anesthetized with various mixtures of N_2O and air and of N_2O, and O, and found that complete anesthesia could be produced by the gas when the blood contained quantities of oxygen fully capable of maintaining consciousness and of carrying on the ordinary process of metabolism. When nitrogen was substituted for the N_2O, the percentage of oxygen breathed remaining the same, the anesthesia gradually passed off and the animal regained consciousness. And it has been found by the late Sir Frederic W. Hewitt[5] that a mixture of nitrous oxid 80 per cent and oxygen 20 per cent (the amount present in air) is fully capable of producing anesthesia in suitable subjects. These observations prove beyond doubt that N_2O possesses specific depressant powers on the central nervous system. It has also been shown by Kemp as well as by others that under N_2O anesthesia the CO_2 content of the blood is greatly reduced below the normal. But in most cases, however, it has been found that the oxygen content of the blood is reduced in even still greater degree below the normal than is the carbon dioxid. As ordinarily administered N_2O causes the nitrogen (and presumably the argon, etc.) contained normally in solution in the blood and tissues to be rapidly washed out of the system. Kemp's blood analyses for the dog show in several experiments a complete absence of nitrogen from the gases drawn off by the vacuum pump. It is to be noted that in all other forms of anesthesia the nitrogen (about 1.7 vol. per cent) remains dissolved in the blood. *Does the absence of this supposedly inactive gas in any way affect the anesthesia?* In many instances I have observed dogs going under the influence of N_2O in which it appeared to me very probable that the elimination of this nitrogen was essential to the production of successful nitrous oxid anesthesia. It is, unfortunately, extremely difficult to prove this point. For one must, as a general rule, empty out most of the air (nitrogen) from the apparatus (and lungs and tissues of the animal) in order to fill this space with nitrous oxid so as to be able to obtain a sufficiently high percentage of the gas to produce the anesthesia. This

makes difficult the solution of the question as to whether or not the absence of the nitrogen in any way influences the nature of the anesthesia. In most forms of nitrous oxid apparatus used heretofore breathing had to be carried on under a greater or less degree of pressure. It is interesting to consider what influence, if any, this may have in tending to dam back the CO_2 produced in the tissues. While this gas did not apparently accumulate in large quantities in the blood in the analyses made by Kemp, still one is inclined to suspect that the tissues may have been trying to form the ordinary amounts of the gas but were either unable to do so or else they could not pass it over to the blood. And any such accumulation of CO_2 in the tissues may very well influence the nature of the anesthesia produced. And similarly any of the immediate precursors of CO_2, is allowed to accumulate in the tissues or blood, may affect the character of the anesthesia produced.

THE SYMPTOMS PRODUCED BY NITROUS OXID.

I have studied this topic both from the standpoint of animals and from that of man.

A frog placed in an atmosphere containing a high percentage (90 to 98 per cent) of N_2O becomes well anesthetized in from three to four minutes. When again placed in fresh air the animal fully recovers in about one minute. Profound anesthesia is readily obtained.

The symptoms in dogs vary greatly with the animal and the method of administration. Fig. 3 shows a record of the respiratory movements in a dog just beginning to inhale N_2O. The animal was lying quietly on the table and made no resistance in any way. The record was obtained by tying a stethograph around the chest wall and connecting it by rubber tubing to a recording tambour. The first part of the tracing shows the normal respiratory movements when the animal was breathing a sufficient percentage of oxygen and the CO_2 was not allowed to accumulate to excess. At the point indicated N_2O was run into the breathing bag and shortly thereafter the depth of the respiration began to increase. This is mainly due to the action of N_2O. It is the typical effect of this gas on the respiration. There is one other point to be considered in the experiment, however, and that is the fact that in this case when the N_2O was run into the bag then the oxygen which the bag contained was considerably diluted. This would also cause the animal to breathe more deeply. But independently of this dilution of the oxygen, the first effects of nitrous oxid in sufficient concentration appear to be to stimulate the respiratory center. After a time, as the animal passes more fully under the influence of the gas, the depth of the respiration decreases while the rate varies somewhat, but on the whole is accelerated beyond the normal. This does not seem to be due to any accumulation of CO_2 in the breathing bag or apparatus, for it is very easy to wash out the CO_2 as fast as it is formed. The animal usually does better, however, if a certain amount of rebreathing and CO_2 accumulation is permitted.

These same phenomena occur in the human subject. It is very interesting to experience the beginning action of the gas. If one fills the bag partly full of oxygen and breathes this for a while (washing out the CO_2), he may at first note a very slight sense of fullness in the head and possibly there may be a feeble flushing of the skin, especially of the face and neck. Whether this is due to a slight CO_2 accumulation in the lungs (dead space, etc.), caused by the small amount of obstruction to the normal respiration, or is due entirely to excitement or the mere feeling that one *expects something* I have not been able to determine. It is of but little consequence, however, and soon passes off as one adjusts himself to breathing into and out of the bag. Slight odors, as from a new rubber bag, or of oil from the pump, sometimes cause one to be a little apprehensive. And the mere act of fixing the attention on the respiration is sufficient to cause certain minor variations in most subjects. When the N_2O is turned on, however, there is an immediate feeling of ease in breathing. The sensation can best be compared to the effect of oiling a new machine. One is somewhat surprised how readily he can breathe deeply and fully and without special exertion. This sensation does not occur if one instead of running nitrous oxid into the bag, should fill it to a corresponding degree with oxygen. I have been inclined to believe, therefore, that it is due to a direct stimulation of the respiratory center by the N_2O. I have considered the question of whether or not the processes of diffusion of the gases in the lungs, or the rate or ease of absorption or excretion of the oxygen or CO_2 through the alveolar epithelium might be influenced in any way by the presence of N_2O rather than of nitrogen. I have not been able to reach any conclusion on these matters. It seems probable that certain obscure changes are produced in the metabolism of the tissues on account of the subnormal CO_2 and oxygen content of the blood, as shown by Kemp. It would be interesting to know whether or not these low percentages of CO_2 and oxygen persist in the blood in those cases in which anesthesia is produced by approximately 80 per cent N_2O and 20 per cent oxygen as in Hewitt's experiments. I

have occasionally believed that in rare instances in dogs which were fully anesthetized I could raise the percentage of oxygen in the bag to perhaps 30 per cent without allowing the animal to revive. In this case, of course, while I might markedly increase the percentage of oxygen in the bag, I did not correspondingly lessen the amount of N_2O in the animal and in the apparatus. In this feature there is a great difference between the apparatus which I have here used and most other forms of nitrous oxid machines, for in these if the amount of oxygen administered is increased, this generally means a *corresponding diminution of the amount of N_2O given with correspondingly increased chances for variations in the character of the anesthesia.*

I have noted only occasionally, as have a number of my students, that just as one begins to breathe a fairly concentrated mixture of N_2O, there may be detected a faint metallic sweetish taste on the tip of the tongue. The sensation reminds one of the taste of saccharin. In my own case this taste has never lasted for more than a second or two, but one student was able to detect it over a prolonged period. It is probable due to N_2O carried in the blood from the lungs to the taste organs.

It will be noted from Fig. 3 that the animal did not struggle as the gas was administered. In some cases I have seen dogs go quietly to sleep and apparently never be conscious at all that they were being anesthetized. In a gentle animal which is especially susceptible to the gas, this may frequently occur. It is by no means the rule, however, and there is often struggling especially if the animal was excited before the anesthesia was started. It is well known that certain human subjects are especially resistant to the gas and I have frequently found this to be true for dogs. In some cases I have been entirely unable to obtain any true anesthesia at all. In these cases cardiac slowing and other complications nearly always come on as one attempts to crowd the gas. This appears to be partly due to stimulation of the vagus center in the medulla for section of the vagi usually accelerates the heart and this is generally even more marked after atropin. I have seen three or four especially striking cases of this kind. An animal which is excited or struggles is much more liable to manifest these cardiac symptoms. After atropin the animal usually takes the gas considerably better, indicating better aeration of the blood in the lungs from the improved circulation. The slowing of the heart may be very marked and apparently may be the cause of death in some cases. I have not taken string galvanometer tracings of the hearts of these animals, but this would be instructive. It has seemed to me in one or two instances that peculiar arrhythmical contractions were set up in the heart and that this finally ended suddenly either with complete stoppage of the heart, or with the establishment of a condition resembling heart block. The cause of these reactions is not at all clear. One would suspect a lack of oxygen, or CO_2 poisoning, but when the CO_2 is well washed out of the gases breathed and the conditions are the same as those under which other animals have been well anesthetized, then one is inclined to look for a difference in the animals. I

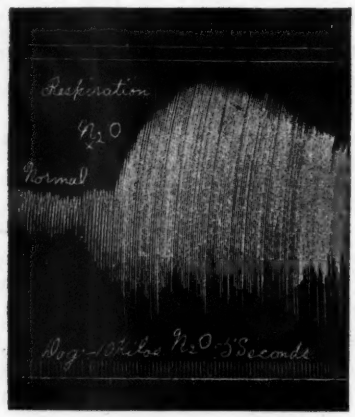

Fig. 3. This tracing shows the respiratory movements of a dog to which (at X) nitrous oxid (plus oxygen) was administered. There is a slight mechanical exaggeration of the respiration record because the animal had been breathing mainly with its diaphragm before the gas was given, but after this the chest movements became much increased. The stethograph recorded more of the thoracic movements than it did of the abdominal.

suspect that very nearly, if not quite this same thing, may have occurred in a few instances in man.[6] For that reason I wish to refer briefly to Fig. 4, which is a tracing of the apex beat of a dog which was given nitrous oxid. The animal was not a good subject, but was finally apparently well anesthetized. After the anesthesia had continued for perhaps half an hour, the pulse in the femoral artery became irregular and finally stopped rather suddenly. With considerable difficulty the animal was revived by means of intermittent compression of the chest. But when the respiration was restored, the animal did not promptly regain consciousness and remained in a semicomatose or somnolent condition for two or three hours. It was noticed about five hours after the animal revived that the heart was irregular and the tracing here shown was made. The animal improved, and in about a week the heart had apparently returned to normal. The animal was kept for forty days thereafter, but no further cardiac disturbance was observed.

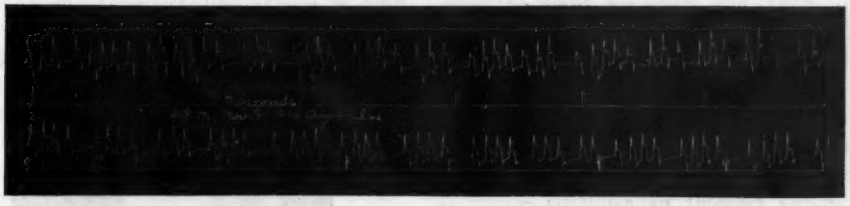

Fig. 4. Tracings of the apex of the heart in a dog in which under nitrous oxide anesthesia cardiac irregularities developed. For a full description, see text. This tracing was taken about five hours after the animal had been anesthetized. At this time it was observed by Mr. John A. Higgins that the animal was in a dazed or semicomatose condition, and that the heart beat was very abnormal. The record here shown was then made.

It seems evident to me that the human subject must be very much more susceptible to nitrous oxid than is the average dog. The anethesia in all cases is of a much lighter form than that produced by ether. In dogs it is as a rule impossible to destroy the corneal reflex, for in the deepest anesthesia in these animals the slightest touch of the cornea or eyelid or even eyelashes causes immediate winking. The eyes remain open and keep up peculiar rolling or staring movements so that one often wonders whether or not the animal is fully anesthetized. If the gas be removed suddenly, however, the animal wakes up and stares about in a way which shows that it had been completely unconscious. During the anesthesia the pupils are dilated but the light reflex is preserved.

The Action of Nitrous Oxid Under Varying Conditions.

If pure N_2O be inhaled, unconsciousness results in a period of from thirty to sixty seconds. But if oxygen be added to the inhaled gas, the time required to produce unconsciousness rapidly increases as the oxygen rises from zero up to five, ten or more per cent. With more than ten or twelve per cent. oxygen content mixtures of nitrous oxid and oxygen usually produce unconsciousness only after considerable periods or not at all, depending on the patient. There seem to be great variations in this respect, however, in the human subject, and I have noted a similar reaction in animals. I should like to emphasize this point in particular since it has a direct bearing on the administration of nitrous oxid by the method which I have here used.

It will be noted by reference to Figs. 1 and 2 that there is a considerable *dead space* in the apparatus. The wash jars, tubes, pump, and the breathing bag all represent space which in the beginning contains air. When the animal is connected to the apparatus then its lungs also add *dead space* to the system. This *dead space* contains oxygen and nitrogen. The oxygen can be readily used up by the animal, but the nitrogen must be gotten rid of. The amount of this nitrogen depends on the construction and size of the apparatus and on the size of the animal. The blood (and tissues) of the animal also contain about 1.7 per cent. of nitrogen which presumably diffuses out into the lungs and is then breathed out when nitrous oxid and oxygen is administered. It is necessary to remove a large part of this nitrogen from the apparatus to secure the best success. This is done by filling the bag partly full of nitrous oxid and running the pump for a while. The animal breathes the mixture of air and N_2O and absorbs a portion of the gas, while at the same time some of the nitrogen in its blood is breathed out. The sodium solution and the sulphuric acid in the wash jars also absorb some nitrous oxid. In a little while the bag is emptied out into the air. This is accomplished by opening a valve on the right (positive) side of the machine while the pump is running. In one or two seconds the bag can be emptied as much as desired and then more N_2O is run in until the bag is about one-half or two-thirds full. This is repeated about three or four times as a rule with dogs. One should not hurry this process. It usually takes at least five minutes to anesthetize a dog deeply and any attempt to crowd the gas faster generally excites the animal and does not improve the anesthesia. It is better to proceed slowly and allow the animal's blood to become as nearly saturated as possible for each concentration of the N_2O. In this manner the action of the drug is brought on slowly and in a perfectly successful experiment the animal may be fully anesthetized apparently without being conscious that anything unusual is occurring. Often it is not necessary to give any oxygen until the animal is anesthetized, for the oxygen in the apparatus and in the lungs serves to keep the animal in good condition for some time. When needed, however, more oxygen should be injected.

It may seem that five minutes is an unreasonably long time to require for the production of nitrous oxid anesthesia. We should remember, however, that much more time than this may be

required with ether, and when we think of anesthetizing an animal in thirty to fifty seconds with nitrous oxid it is interesting to consider the possibility of doing this same thing with chloroform or ether vapor which are exceedingly well absorbed by the blood. And it is probable that in any rapidly produced nitrous oxid anesthesia there may be a considerable element of asphyxia which is undesirable.

In this connection I should like to refer to some physiological experiments[7] on respiration which involve certain features usually concerned in nitrous oxid anesthesia.

"1. *The Immediate Effects of Total Rebreathing (Due Chiefly to Excess Carbon Dioxid).*—The nostrils are compressed with a nose-clip and the subject breathes from and into a rubber bag containing 20 to 40 liters of air. The amplitude of respiration is soon augmented, and in the course of a few minutes the subject is panting heavily forty times a minute. He usually develops a typical carbon dioxid headache, but this wears off in fifteen or twenty minutes after the experiment is ended." These results are produced by breathing for a *few minutes* into a closed bag. If in addition to these effects, which are due chiefly to carbon dioxid accumulation, there be added the further effects of oxygen want which are usually present from the very beginning in the administration of nitrous oxid, what will be the results of these purely physiological phenomena when complicated by the addition of nitrous oxid in those forms of apparatus in which rebreathing into and out of a closed bag is carried on for considerable periods of time?

"2. *The Effects of Insufficient Oxygen Without Excess of Carbon Dioxid.*—The above mentioned bag is refilled with 20 to 40 liters of fresh air and the experiment performed again, but with this difference, that a vessel of 1 or 2 liters capacity filled with soda-lime or broken sticks of sodium hydrate is placed between the bag and the subject's mouth so that he breathes through it into and from the bag. The carbon dioxid exhaled by the subject is thus absorbed, and he gradually consumes the oxygen in the bag. As a rule there is *no noticeable deepening or quickening of the breathing,* and the subject will first become cyanosed and then unconscious without appreciable augmentation of breathing. This experiment should *always be carefully supervised,* as it is not free from danger. If continued for more than ten minutes, it is usually followed by a severe frontal headache, developing slowly for several hours thereafter, together with other ill effects and lasting from twenty-four to forty-eight hours." It is particularly interesting to consider this experiment in connection with

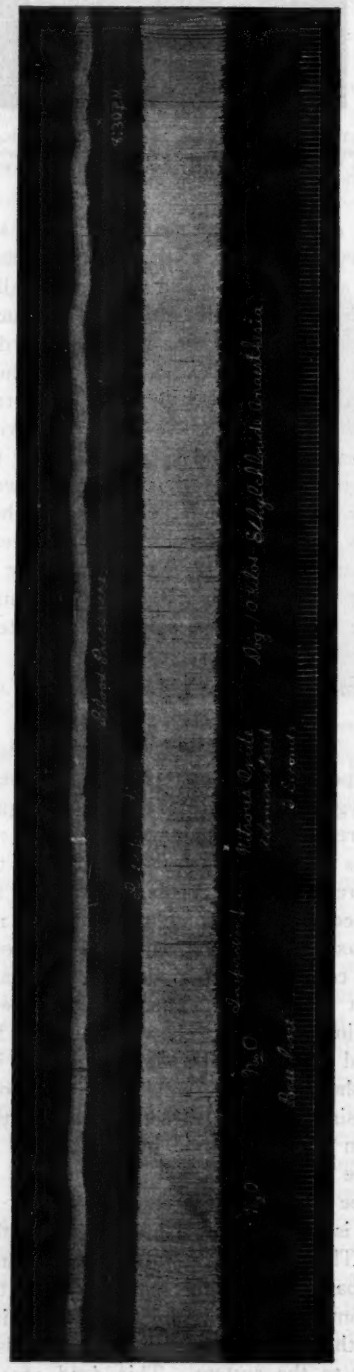

Fig. 5. Blood pressure and respiration in a dog anesthetized with ethyl chlorid. At three places, as shown on the record, nitrous oxid was run into the breathing bag. This was done in order to observe the effects of the gas on the circulation and respiration. The results were practically nil so far as can be observed from the record.

those forms of nitrous oxid apparatus in which the patient inhales the gas (plus a varying but usually small amount of oxygen) from a tank or

reservoir and then exhales out into the open air. In these machines the carbon dioxid is probably fairly completely removed as fast as it is exhaled from the lungs. The small percentage of oxygen usually given (e.g., from two to ten or twelve per cent.) with the nitrous oxid may cause a rather close simulation of the conditions established in the above experiment in which *cyanosis* and *unconsciousness* may be produced *without any anesthetic.* I should like to give one further quotation bearing on the point from Haldane and Poulton.[8] * * * "Still more sudden exposures to anoxemia occur when air containing little or no oxygen is breathed; for in this case the oxygen previously present in the alveolar air, and even in the venous blood, is rapidly washed out; the result is that consciousness is suddenly lost *without evident preceding hyperpnea,* although abundance of CO_2 is present in the arterial blood. Haldane and Lorrain Smith observed sudden loss of consciousness after 50 seconds on breathing air which was afterwards found to contain 1.8 per cent. of oxygen. During any exertion the loss of consciousness is still more sudden. This is a common experience with miners going into an atmosphere of nearly pure fire damp (CH_4), or climbing up so that their heads are in the gas, that they drop suddenly as if they were shot."

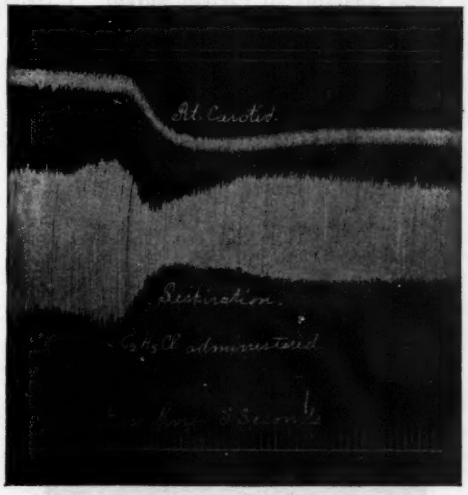

Fig. 6. This animal was anesthetized with nitrous oxid. At the point indicated ethyl chlorid was injected into the bag. There is an immediate fall in pressure and the respiration is much diminished.

I do not care to discuss this point further, but may state briefly that my own experiments, together with the results obtained by others, have led me to conclude that it is impossible to obtain a rapid (1 minute) production of anesthesia and unconsciousness in dogs with nitrous oxid and oxygen at atmospheric pressure unless the oxygen content of the mixture is so low that the loss of consciousness is due *almost entirely* to the lack of oxygen. Presumably, with certain modifications, this is true in the human subject also. On the other hand it seems probable that in all dogs which do not possess a special idiosyncrasy against the gas, mixtures of nitrous and oxid and oxygen containing sufficient amounts of the latter to avoid most if not all asphyxial effects, may be used to produce anesthesia *provided sufficient time be allowed for the gas to act and the CO_2 be completely removed as fast as it is excreted by the lungs.* If a high per

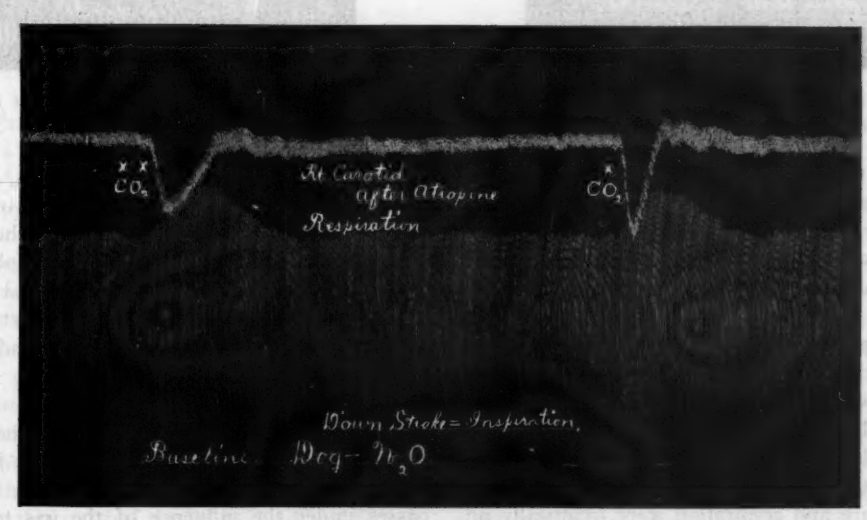

Fig. 7 This tracing was made in a class experiment by Messrs. Mitchell, Day, Lucking and McKee. It shows the results produced on the respiration and blood pressure by injecting (twice) a small amount of carbon dioxid into the breathing bag while the dog was anesthetized by nitrous oxid. In each case the CO_2 was quickly emptied out of the bag after the animal began to show marked symptoms.

cent of oxygen is used, anesthesia cannot be quickly produced but asphyxia may be avoided. The time required may be considerable, perhaps from five to fifteen minutes or longer. But as the tissues gradually become more and more saturated with the gas, there will be a gradual depression of the central nervous system which will finally result in unconsciousness.

It was long ago observed by Goldstein[9] that anesthesia appears more quickly and with a proportionately less degree of asphyxia, the higher the organization of the brain—namely, earlier in man than in laboratory animals. I have been able

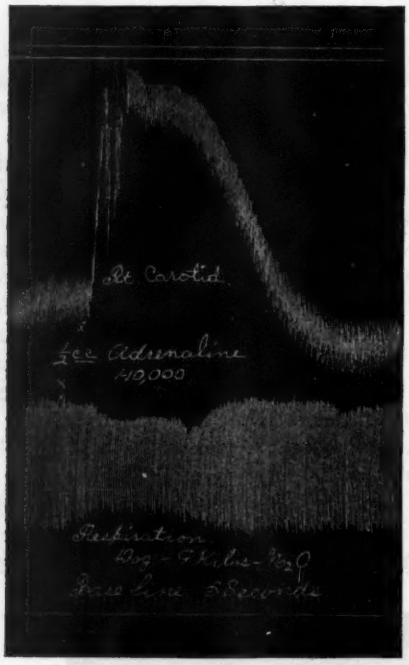

Fig. 8. The animal was anesthetized with nitrous oxid. At the point indicated adrenaline (1/4 c.c. 1-10,000) was injected intravenously. The vagi were intact. (For discussion, see text.)

to confirm this observation many times. And in addition the anesthesia appears as a general rule to be deeper in man than in dogs, although in some animals a profound anesthesia may be readily obtained if all carbon dioxid effects be carefully avoided.

It seems probable that in average cases the heart and circulation are not much affected by the gas. Fig. 5 shows the result produced by injecting nitrous oxid into the breathing bag when the animal was already anesthetized by ethyl chlorid. Three injections were made but the effects on both blood pressure and respiration were practically nil. This corresponds very well to the injection of an ordinary drug solution into the femoral vein when an animal is anesthetized with ether. (Fig. 6 shows the reverse of this experiment and illustrates the action of ethyl chlorid on an animal already anesthetized by nitrous oxid.) As a kind of check on these experiments another tracing (Fig. 7) is shown in which at two places a small amount of carbon dioxid was injected from a tank into the breathing bag. There is an immediate stimulation of the respiration and the blood pressure falls, probably from a direct action on the heart. The gas was quickly emptied out and the bag was again refilled with nitrous oxid plus a suitable amount of oxygen. This shows quite well the action of even small amounts of carbon dioxid. I strongly

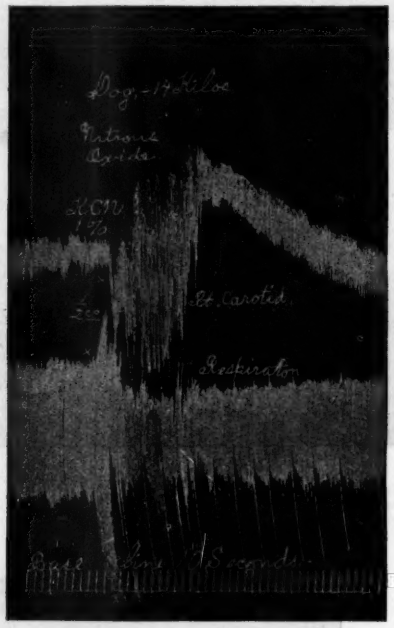

Fig. 9. Dog anesthetized with nitrous oxid. At the point indicated 1/2 c.c. of 1 per cent. KCN was injected intravenously. The vagi was intact. (For discussion, see text.)

suspect that some such action as this, either by excess of carbon dioxid, or from lack of oxygen, or both, constitutes the real cause of the undesirable after effects which are liable to follow from prolonged nitrous oxid anesthesia. And I am inclined to believe that these after effects may be very generally avoided by a correct and scientific administration of nitrous oxid.

I have repeatedly observed, as have others, independently in my laboratory, that if one breathes a mixture of nitrous oxid and oxygen for a certain time, for example five minutes, and then passes under the influence of the gas to a given degree, he can then considerably increase the quantity of oxygen in the bag without lessening the in-

fluence of the nitrous oxid so far as the subject of the experiment himself can determine. The reason for this appears to be as follows: On breathing the N_2O at first the whole body of the subject after a time becomes saturated with the gas at the given partial pressure. (As the first portion of gas is absorbed, one can see the bag shrink fairly rapidly with animals.) More N_2O must be run into the bag to replace that absorbed. But after the anesthesia or analgesia has reached a given degree, then if no more gas, but only oxygen, is given, the effects of the N_2O on the subject should remain fairly constant. It will be noted

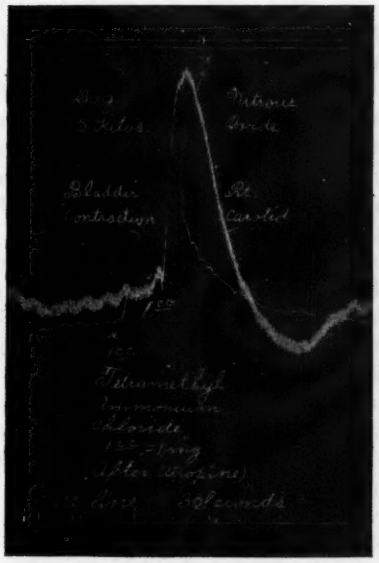

Fig. 10 Dog anesthetized with nitrous oxid. The tracing shows the blood pressure (Rt. carotid) and the bladder contractions (up-stroke). At the point indicated 1 c.c. of tetramethylammonium-chlorid was injected intravenously. The animal had previously received 1½ mgs. of atropin.

that the gas is excreted only into the bag from which in a given time approximately the same quantity of N_2O will pass back again into the blood. Supposing the bag was filled to the amount of two gallons (For clearness of description I have assumed that the *volume* of one gallon of the gas may be considered equal to the volume of four quarts. We need not consider variations of temperature, pressure, etc.) with 90 per cent N_2O and 10 per cent oxygen. If then one adds a quart of oxygen to the bag the per cent of oxygen the patient would breathe should be increased by one-ninth of the total amount of mixed gases in the bag after the quart of oxygen is added. It would appear that this oxygen should be readily absorbed by the lungs in approximately the same proportion and quantity as oxygen is absorbed by the blood from the air (which contains oxygen in about the same proportion as the bag would now contain it, i.e., about 20 per cent). This would probably not be quite correct, for nitrous oxid has some power to displace oxygen from its solution in water (Sir Humphrey Davy[10]), and this probably holds good for the blood in the pulmonary capillaries also. On the other hand, when the quart of oxygen is run into the bag, the latter will be expanded by a volume equal to one quart and into this space the nitrous oxid already in the bag and also that dissolved in the blood and tissues of the subject, may diffuse. But if, for example, the blood and tissues of the subject had absorbed two gallons of N_2O

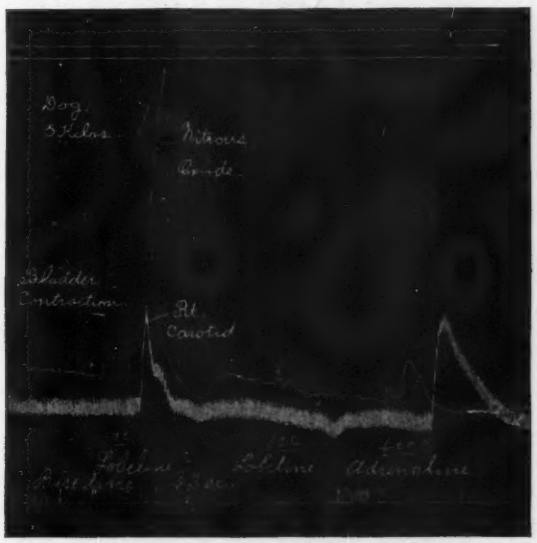

Fig. 11. Dog under nitrous oxid anesthesia. Bladder contractions (up-stroke) and blood pressure. At the point indicated (on the left) 1 c.c. of lobelin was given intravenously. A marked contraction of the bladder and a small rise in blood pressure were produced. A little later a second dose of 1 c.c. of lobelin was given. Almost no results were produced by this, showing that the first dose of lobelin had produced ganglionic paralysis. Later a small dose (½ c.c.) of adrenalin was injected. This gave a slight bladder contraction and a small rise in blood pressure.

and the bag contained two and one-fourth gallons of (mixed) gases after the quart of oxygen was added, then there would be a chance for the N_2O to be diluted by approximately one-seventeenth of the total volume of gases or 5.8 per cent. At that time the subject might be breathing almost 20 per cent of oxygen and this is readily absorbed by the hemoglobin of the blood. In other words, the relative increase in percentage of oxygen breathed when a given amount of oxygen is added to the bag, is greater than is the relative amount of dilution of the nitrous oxid with which the subject is saturated after the oxygen is added to the bag.

It was shown by Van Arsdale[11] in 1891 that the breathing of nitrous oxid to and fro from a bag in

which the gas (plus the desired amount of oxygen) was contained at an increased pressure above that of the atmosphere caused an increase in the depth of the narcosis produced. (This was an entirely different principle from that which Paul Bert[12] and later Claude Martin[13] used in which the patient or animal was placed in an air-tight room, the air pressure in which was raised one-fourth above that of the atmosphere after which 80 per cent N_2O plus 20 per cent oxygen was administered to the patient or animal.) I have tried to verify Van Arsdale's results many times. In some cases (with dogs) increasing the pressure of the gas in the bag does deepen the anesthesia, but in many other cases I have not been able to demonstrate any advantage from this increased pressure. Perhaps the increased respiratory exertion, the marked hindrance to the pulmonary circulation and the attendant obstruction of gaseous exchange in the lungs were sufficient in many cases to overcome the advantages of the increase in absorption of the N_2O which the raised pressure might bring about.

The intravenous injection of adrenalin in an animal under nitrous oxid anesthesia gives a practically normal reaction, i.e., the record is almost exactly like that produced by adrenalin in an animal under ether. The rise in pressure here probably supplies more oxygen to the brain and whatever asphyxia may have been present from the administration of the nitrous oxid is thereby reduced (see Fig. 8). On the other hand, the injection of cyanides (which are supposed to cause an internal asphyxia by lessening the tissue oxidations through inhibiting ferment action) causes a markedly increased reaction both as regards the respiration and the circulation. The animal also shows a more marked convulsive reaction than it does under ether (see Fig. 9). I have controlled this by anesthetizing the animal first with N_2O and obtaining records of the blood pressure and respiration from the cyanides and then giving the animal ether, after which more records were obtained.

The motor areas are much more sensitive under nitrous oxid than under ether. One can easily secure very extensive movements of the muscles of the opposite side and can readily pick out the areas for individual groups of muscles. I have observed that dogs under nitrous oxid anesthesia may not well withstand extensive operations, particularly if the abdomen is opened and the viscera manipulated in any way.

In several respects there is a striking similarity between the effects of nitrous oxid and those of morphin in dogs. Among these may be mentioned the production of Cheyne-Stokes respiration. This is generally present in prolonged anesthesia in dogs. The irritability of the cord is also much less depressed than is the case with the methane series of anesthetics and this action also closely resembles that of morphin. As under morphin defecation also sometimes occurs, but I have generally been inclined to attribute this to asphyxia, although other factors may be involved. A peculiar feature is often noticed in the fact that the dogs, while lying quietly and apparently fairly well anesthetized, may be aroused and waked up by stimulation or shaking in a manner very similar to that possible under a moderate dose of morphin. When thus aroused there is also often observed a marked acceleration and increase in the strength of the heart beat. If the animal be again left alone it will soon return into the somnolent, or perhaps analgesic state, very much as occurs after morphin. It is difficult to study the analgesic effect of nitrous oxid separately and apart from the production of total unconsciousness in dogs, for these animals, so long as they are conscious, are very likely to struggle and try to escape even though they feel no pain whatsoever.

The thought has occurred to me many times that nitrous oxid might be used as a hypnotic. By ordinary methods of administration this is obviously impractical. But by a slight modification of the apparatus which I have used I am inclined to believe this idea might be very well put into practice. I have tried repeatedly to compare the mild on-coming effects of the gas as breathed with a considerable proportion of oxygen with the physical and mental sensations present as one begins to fall asleep. There is a very striking similarity, a marked feeling of tiredness and exhaustion, the limbs feel heavy and the eyelids tend to close. One's mentality gradually sinks and there is difficulty in maintaining connected thought. The natural inclination of the subject of the experiment is to lie down quietly and fall asleep. The sensations remind one of the feelings of a child worn out by a long day's play when it lies down at night to sleep. Sometimes I have noted slight muscular twitchings or feeble jumping or convulsive movements. These would probably not occur if the gas were administered very slowly with plenty of oxygen and a sufficiently long period of time were used to bring on the action of the drug. Suggestion appears to play a noticeable part in this action, for if one keeps perfectly quiet and at rest and tries to go to sleep, then the somnolent action of the gas is especially liable to be well marked. It would appear that this matter of suggestion extends even to dogs. For an animal which is petted

and induced to lie down quietly and at complete rest may very often take the gas readily and peacefully fall asleep.

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PATHOLOGICAL PULMONARY CHANGES FOLLOWING INTRATRACHEAL ANESTHESIA FOR EXPERIMENTAL LUNG SURGERY.*

CONRAD GEORG, JR., M.D.
Demonstrator of Surgery, University of Michigan.
ANN ARBOR, MICH.

Although much experimental work has been done upon the surgery of the lungs and some operations of this kind have been successfully performed upon man, it still continues to be a dangerous field for surgery and some facts may yet be discovered experimentally which will prove of practical value in performing these operations upon man.

The experimental work which forms the basis of this paper was done by means of Meltzer's insufflation apparatus in which the pressure was furnished at first by the operation of a pair of bellows and later by means of compressed air.

The use of intratracheal insufflation to maintain an adequate pressure of air while operating upon the thoracic organs has been known since the time of Vesalius who in 1560 discovered that he could prolong the life of an animal after opening its thorax to study the motions of the heart by blowing through a tube introduced into the trachea.

Robert Hook on October 29, 1667, delivered an address before the Royal Philosophical Society in which he showed that the respiratory movements were simply for the purpose of bringing about a supply of fresh air to the lungs. He experimented upon a dog, opened its chest and kept it alive by blowing air into its lungs by means of bellows, occasionally permitting the lungs to collapse and then distending them. Upon ceasing the blast the dog would fall into dying convulsive fits but revived again upon inflating the lungs.

During the latter part of the eighteenth century the bellows were generally used in England to resuscitate people who had been drowned and it was then known that there was danger of over distension of the lungs if the blast was made too vigorously.

Desault in 1790 introduced a rubber catheter into the trachea in order to relieve difficult breathing due to stricture of the larynx. In 1827 Le Roy pointed out that if a very high pressure were maintained with the bellows it might result in emphysema and death. The use of an introlaryngeal tube for croup was described by Bouchut in 1857-58, and O'Dwyer of New York described his intubation apparatus for diphtheria in 1885. In 1887 Fell of Albany described his method of artificial respiration by means of a pair of bellows and a tracheotomy tube. Francois Frank brought out two forms of positive pressure apparatus in 1896. In the same year Quenu and Longuet made a positive pressure apparatus and Tuffier advocated insufflation in operations upon the pleural cavity. This was tested experimentally upon animals and clinically in operations upon man in the hospitals of Paris. In Quenu's apparatus the head was placed in a chamber which resembled a diver's helmet. Compressed air and chloroform were used for the insufflation. In 1900 Matas employed the Fell-O'Dwyer method in intrathoracic surgery.

In 1904 the attention of experimenters in intrathoracic surgery was somewhat diverted from the use of positive pressure by the researches of Sauerbruch of Germany. The latter, following the advice of Mikulicz had done considerable experimentation with the object of overcoming the ill effects of pneumo thorax during and after intrathoracic operations by the use of negative pressure. Woillez in 1875 had already invented his *Spirophore* which made use of negative pressure. Sauerbruch enlarged the *spirophore* at first to the size of a small cabinet just large enough for operating upon dogs and later on into the form of a cabinet large enough for operations upon man. As a result of much experimentation upon dogs Sauerbruch concluded that positive

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pressure produces numerous disturbances in the normal circulation in the lungs. Brauer (1904) and Seidel (1907), however, found that the changes were so slight as to be of no importance when only enough positive pressure is used to prevent pneumothorax. Cloetta (1910-1913) made some experiments with a special lung plethysmograph to determine the effects of positive and negative pressure upon the circulation in the lungs. He resected the chest wall and placed the lungs in a glass plethysmograph and stopped the respiratory movements by the use of curare. In this manner he proved that if the lung is distended to the same degree exactly by positive and negative pressure, one-third less pressure is required with the negative than with the positive or if the same amount of pressure is used in each case the lung will be more distended with negative pressure. Furthermore, he showed that with the same distension of the lungs, the aortic pressure falls more with positive pressure than negative and that the pressure in the pulmonary artery rises higher with positive pressure and there is an increased diastolic pressure in the right ventricle. A high degree of positive pressure results in compression of the lung capillaries. Experience has shown that a slight degree of positive pressure is not dangerous but high or long continued pressure may result in serious reflex disturbances in the lungs and deleterious effects upon the circulation, depending upon the reserve power of the right ventricle.

All animal experiments seem to show that total extirpation of one lung has a higher mortality with positive pressure than negative, because the pressure of air in the empty pleural cavity which cannot be entirely driven out prevents the collapse of the chest wall and change in position of the diaphragm, mediastinum and sound lung which is necessary for recovery. These facts have been well established by experimental evidence. Block, Gluck and Schmid made researches of this kind in 1881. Biondi in 1884 obtained four recoveries in fifteen operations. Mayer of Brussels reported two recoveries in seventeen total pneumectomies on dogs. Janeway removed one entire lung in five dogs with recovery, using positive pressure. Sauerbruch and Haecker, using positive pressure, lost thirty-four dogs out of thirty-eight in their first series of experiments. The extirpation was done through one intercostal incision. Eleven died of leakage from the bronchial stump, five from primary infection at the time of operation and eighteen from the pressure resulting from pleural exudate. In the second series of twelve dogs, eight died.

Robinson in 1908 reported a series of thirty thoracic operations on dogs by means of his positive pressure apparatus. In this series there were nine deaths and twenty-one recoveries. There were nine simple pleurotomies with two deaths and seven recoveries. One experiment was merely the application of the positive pressure without opening the thorax to demonstrate whether the method of anesthesia was dangerous in itself and this ended in recovery. There were nineteen excisions of the lung with seven deaths and twelve recoveries. Another experiment consisted in clamping and releasing the lower lobe of the lung and ended in recovery.

Willy Meyer under a combination of positive and negative pressure performed twenty-one total excisions of the lung with seventeen recoveries. Removal of one or more lobes was done six times with five recoveries. In a series of twenty-four cases there were twenty-two recoveries. At one time twelve dogs were operated upon without a single death. Giertz operating with positive and negative pressure, used a flap of the fascia lata for covering the wound in the lung after resection and had eight recoveries out of ten operations upon large dogs. In rabbits there were no deaths. Robinson and Sauerbruch in 1910 found they got better results by resecting four ribs when a complete extirpation of one lung is done than if the operation is done through an intercostal space. The collapse of the chest wall thus obtained helps to close off the space left in the chest cavity thus tending to prevent pneumothorax but if a larger resection is done the animal may die because the operated chest wall offers no resistance to pressure within the sound lung, as a result of which the thin mediastinum is apt to rupture, resulting in a double pneumothorax.

Schlesinger in 1911, using Meltzer's apparatus, did seventeen total pneumectomies with five recoveries. He generally found air in the pleural cavity postmortem in the operated side and sometimes in the unoperated side. Kawamura (1914) has successfully removed the entire left lung of dogs and in a few instances a part of the right lung also at a second operation. This was done by means of Shoemaker's positive pressure apparatus.

So far there have been sixteen cases of pneumectomy in man with eight deaths. Helferich, 1898, removed the middle and lower lobes of the right lung in man for sarcoma of the chest wall. Heidenhein in 1901 removed the left lower lobe of the lung for bronchiectasis and this was followed by a fistula. Stretton in 1906 successfully resected the upper lobe of the right lung for tuberculosis. Robinson in 1912 removed the lower lobe of the left lung for bronchiectasis. Kümmell in 1911 removed the entire right lung from a man, 48 years

old, for carcinoma. This patient died on the sixth day from edema of the lungs and tracheal rattling. Postmortem showed necrosis of the lung stump on account of the fact that the bronchi and vessels of the lung were clamped with forceps.

Resection of the lung is a very dangerous operation both on dogs and on the human being on account of the danger of pneumothorax and of the difficulty of making a hermetic closure of the bronchus and lung. Infection may also take place from the outside if the wound gapes open or drainage is used. Another source of infection of the lungs and bronchi may result from the presence of germs in the nose and throat which are driven inward by the insufflation apparatus. This is particularly true of dogs which are affected with distemper as may be seen from my experiments. Distemper is a nasopharyngeal catarrh occuring in dogs and caused, as Ferry proved, by the bacillus, bronchi-septicus. The disease is accompanied by respiratory, abdominal and nervous symptoms and often results in death. It is the common presence of this infection in dogs together with their necessary confinement in laboratories, when accustomed to an out-door life, which lowers their resistance to surgical operations and makes the results of experimental surgery much less favorable than the same operations upon man.

The statistics of experiments in lung surgery with positive and negative pressure show much better results with the latter because it produces conditions closely resembling the physiological. Robinson and Sauerbruch in 1909 concluded that the space left behind after doing intrathoracic operations under negative pressure diminishes rapidly but that this is not the case in such operations done under positive pressure as most of the dogs died from the formation of an exudate. I found similar results in my experiments. Kawamura, however, found no exudate after his operations although he used Shoemaker's positive pressure apparatus. The great difficulty in these operations is to prevent pneumothorax and infection, both from the interior of the lung and the outside, without causing any damage to the histologic structure and circulation in the lungs.

Dogs are especially unfavorable subjects for these operations on account of the shock which results from exposure and loss of body temperature, their inability to stand pneumothorax well and their low resistance to infection in the pleural cavity. They bear peritoneal infection very much better as can be seen from the numerous successful abdominal operations that have been performed upon them. The pleuritic exudate which generally forms after these operations acts unfavorably because the normal circulation is important for the elimination of germs from the pleural cavity as was proved by Nötzel's experiments. This fluid is absorbed very much more slowly by the inflamed than by healthy pleura. Grober in 1901 thought that this slow absorption was due to the fact that the stomata are closed by fibrin and that the endothelium is damaged by the inflammation. The same is true of the absorption of air in pneumothorax. Dorpat in 1893 showed that 78 cubic centimeters of air was absorbed in twenty-four hours by a dog weighing 11.7 kilograms, but that it took four days to absorb 35 cubic centimeters of air when the pleura is inflamed.

The exudate which forms after a thoractomy causes compression of the lung which has a bad effect upon its circulation and function. Secondary infection of the compressed lung may result in the formation of areas of pneumonia as may be seen from my experiments. Drainage is apt to be allowed by pneumothorax and secondary infection of the pleura. In experiment VI where the entire left lung was removed, the entire pleural cavity on that side was filled with a thick fibrinous coagulated exudate. This was nature's effort to overcome the bad effects of pneumothorax. Tiegel invented a drain which allows fluids to escape, but prevents the entrance of air or fluid into the pleural cavity. In the case of wounds of the lung in man, pneumothorax can be prevented by the use of Tiegel's drain and emphysema may be treated by aspiration according to Bier's method.

The peculiar anatomy of the dog's thorax gives it very little resistance to penumothorax. In this respect it differs from the rabbit very much. The thorax in man offers considerable resistance to pneumothorax as in only about 5 per cent. of intrathoracic operations does it become necessary to use any apparatus to prevent pneumothorax. Surgeons have known this in the past because numerous operations have been done for empyema and lung abscess without the use of any differential pressure apparatus. In chronic cases of empyema, owing to the formation of firm adhesions between the lung and parietal pleura and because of the fixed position of the mediastinum it is possible to resect portions of all the ribs of one side without danger to life. Children can usually stand extensive resections of the chest wall and lung because their relatively soft chest wall can readily contract and the diaphragm lies high so that the space which is left behind soon becomes closed off. Conditions in the rabbit are similar.

In the dog these conditions are entirely different

as the animal will die in a few minutes if a wide opening is made in the chest without the use of differential pressure. In this animal the mediastinum is a wide, very delicate and transparent membrane and there is a mediastinal band extending from the neck to the diaphragm. On this account it is unable to resist any marked changes of pressure within the thorax without injury to the heart and pulmonary circulation. The thickness and rigidity of the mediastinum in rabbits enables them to stand pneumothorax for a long time. Although the operated lung and heart follow the mediastinum into the normal side of the thorax during inspiration, still the mediastinum gets into its normal position during expiration. In the case of the dog the mediastinum is so loose and delicate that it flutters up into the wound and often becomes perforated thus allowing air to get into the sound half of the thorax resulting in double pneumothorax. In consequence of this the pressure of the external air in the opened side of the thorax exercises dangerous compression upon the normal lung which is unable to drive the air out entirely even with the help of the diaphragm and the accessory muscles of respiration. Le Play and Mantoux showed that by induced pneumothorax they could render all but one-sixth of a dog's lungs atelectatic without causing death.

INTRATRACHEAL INSUFFLATION.

In 1910 Meltzer introduced his method of intratracheal insufflation for the purpose of maintaining a positive pressure within the lungs in order to prevent pneumothorax during intrathoracic operations. The technic of this method was established by a long series of experiments upon dogs. A soft rubber catheter is introduced through the larynx into the trachea after the patient has been thoroughly anesthetized. The lower jaw is propped widely open and the tongue is drawn forward until the epiglottis is recognized. The latter is then drawn forward with a long pair of curved forceps and the catheter passed along the forefinger until it enters into the larynx. The catheter should be provided with a terminal opening instead of a lateral one. After the catheter is introduced as far as it will go it is deeply in the right bronchus and it should be slightly withdrawn (about 5 to 6 centimeters) and secured in position so that it will not slip out of place. It should be determined whether the catheter is in the trachea or esophagus, as acute dilatation of the stomach will result if it is in the latter. This will prove fatal unless the air is removed from the stomach by disconnecting the catheter with the apparatus and making pressure over the stomach until the distension is relieved.

After the catheter is attached to the insufflation apparatus, ether mixed with air is blown into the lungs either by pressure upon a pair of bellows or by a connection with a compressed air apparatus. This apparatus is connected with a mercury safety valve which is set at 30 millimeters so that if the pressure in the apparatus exceeds that point the excess of air will bubble off through the mercury. The average pressure which should be maintained for intrathoracic operations upon dogs is 18 to 25 millimeters. The pressure in operations upon man may be raised to 35 to 40 millimeters. Meltzer considers it safe at any point below 50 to 60 millimeters. There is also a valve attachment to the apparatus for the purpose of releasing the pressure in the lungs about six times a minute for a period of two seconds at a time to prevent shock and damage to the lungs. This also relieves the obstruction to the flow of venous blood to the right auricle from the great veins of the chest and abdomen. The size of the French catheter varies from 18 to 24 or with a diameter of 8 millimeters and a lumen of 4 millimeters according to the size of the animal.

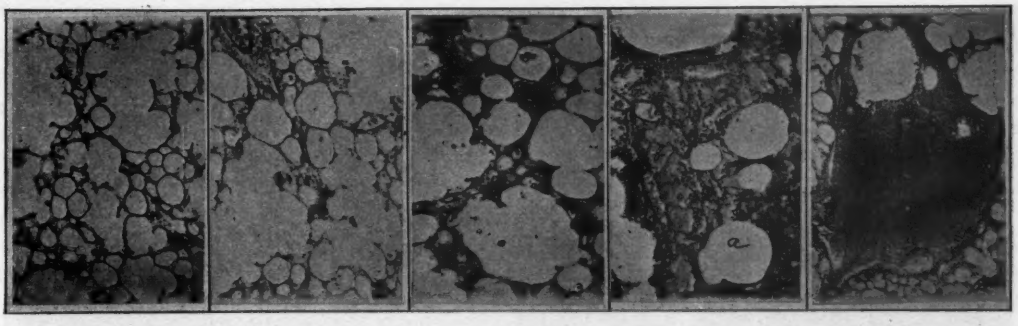
This method of anesthesia will not be accompanied by asphyxia if the catheter is of the proper size and the blood is well aerated. My experiments show that it does cause some damage to the alveoli of the lung. Severe shock and reflex disturbances are likely to follow this method of anesthesia if the pressure within the lung is maintained at a point higher than 25 to 30 millimeters.

Sauerbruch proved by animal experimentation that the breathing capacity can be reduced to one-tenth of normal without endangering the oxygen content of the blood. Spontaneous breathing should take place at all times during the anesthesia.

Seidel showed that there is a fall in blood pressure upon interrupting the pressure in the lungs. This fall in blood pressure was equalized so that it returned to normal before the cessation of the interruption. The pulse curve also showed some irregularity.

Robinson reported in 1913 that intratracheal anesthesia had been used in 1,402 cases with seven deaths. It is very useful in operations about the mouth, nose and throat as well as those within the chest, because blood and mucus cannot enter the glottis.

A series of pneumectomies were performed upon dogs at the Surgical Laboratory of the University of Michigan, using Meltzer's apparatus for intratracheal insufflation in order to determine whether there are any serious dangers connected with this method of anesthesia. The technic which was used in these operations was as follows: The field of



CASE IX. Photomicrographs of sections of (1) unoperated lung, acute emphysema; (2) unoperated lung, acute emphysema, ruptured alveolar walls, congestion, areas of hemorrhage; (3) operated lung, *a*, emphysema, *b*, hemorrhage into alveoli, congestion and edema; (4) operated lung, acute emphysema, rupture of alveolar walls, congestion and edema; (5) operated lung, acute emphysema with rupture of alveolar walls.

operation was shaved on the day before the time set for operation. The dogs were given nothing to eat for twenty-four hours previous to the operation. A hypodermic of morphin gr. ¼ and atrophin gr. 1/150 was given one-half an hour before the beginning of the anesthesia. This dose was doubled in the case of the large sized dogs. After placing the animal upon the table the field of operation was scrubbed with a sterile brush and soap followed by sterile water, acetic acid and alcohol then sterile water again followed by a solution of bichloride of mercury 1-1000.

After the animal was completely anesthetized the catheter was introduced through the larynx into the trachea until it met an obstruction, then it was withdrawn about five centimeters and attached to the insufflation apparatus. The same aseptic technic was followed in these operations as is customary in any major operation upon man in a modern hospital.

The following are reports of those experiments of which the microphotographs of pathological pulmonary changes are presented;

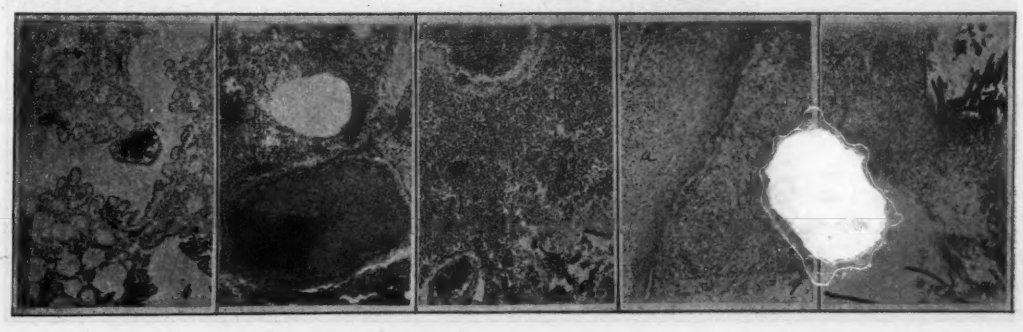
CASE IX. Operation: Resection of one lobe of left lung. Result: Death in two days.

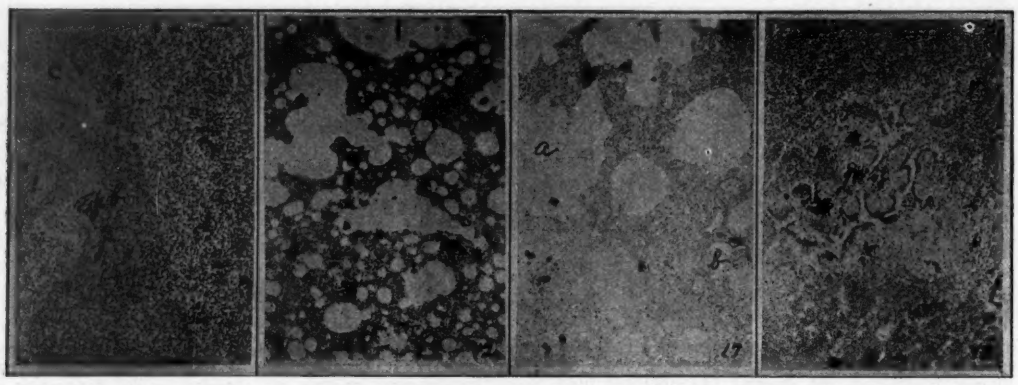
May 19, 1914, 8 P. M.—Miss Davis gave anesthetic. The same aseptic precautions as in any hospital surgical operation. Towel clamps applied. End of intratracheal catheter cut off so that it had a terminal instead of a lateral opening. Incision in seventh intercostal space. The distension of the lung was good, ribs retracted with mouth gag, lung grasped with rubber protected clamps and one lobe removed. The bronchi were ligated, cautery applied to wound and the lung carefully sutured. A drainage tube was introduced about two inches from the spine and only to edge of pleura. The air around the operated lung was aspirated with a small air pump and a rubber dam was applied over the tube and sutured into position. Aseptic dressings applied.

May 20.—Dog jumped out of box, dyspnea present.

May 21.—Dog died. Edema of all the tissues and fluid found in both pleural cavities. Tube was blocked with fibrin.

CASE XIV. Photomicrographs of sections of (6) unoperated lung, some emphysema, anthracosis, marked dilitation of bronchioles; (7) unoperated lung, emphysema, congestion and anthracosis. CASE XV. Photomicrographs of sections of (8) operated lung, nearly complete atelectasis, partial collapse of smaller bronchi, congestion; (9) operated lung, *a*, thick fibrino-purulent pleural exudate, *b*, collapsed lung; (10) operated lung, *a*, purulent pleural exudate, *b*, embodied stitches.





CASE XVII. Photomicrographs of sections of lung, (11) operated, *a*, atelectasis, *b*, anthracosis, *c*, scar tissue; (12) operated lung, some emphysematous areas and anthracosis. CASE XIX. Photomicrographs of sections of (17) operated lung, *a*, emphysema, *b*, hemorrhagic area; (18) atelactasis, collapse of bronchi, congestion, hemorrhage and anthracosis.

"Postmortem examination shows acute emphysema, rupture of the alveolar walls, congestion and edema. The large tear appears to be postmortem," Warthin. I had inserted the catheter into the trachea and insufflated with the bellows to see how much pressure the lungs would stand without rupturing. No rupture was noticed on the surface of the lung. A moderate distension, therefore, is all the lungs will stand during insufflation without the lungs being so badly damaged internally that the patient cannot recover.

CASE XIV. Operation: Resection of one lobe of left lung. Result: Recovery.

December 29, 1914, 8 P. M.—Dog weighs 19.8 kilograms or 44 pounds. A number 24 French soft rubber catheter was used for intubating the larynx and trachea, and the pressure kept at 25 to 30 millimeters.

Operation performed by Drs. Hayes and Cattermole under strict aseptic precautions. A strip of the fascia lata was used to cover up the wound in the lung.

December 30.—Dog stands up in cage, respirations 40, pulse rapid. Bowels have moved

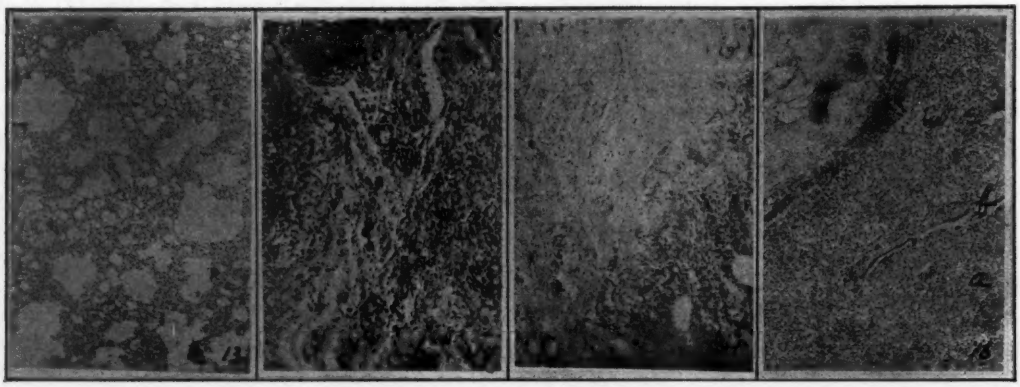
December 31.—Respirations 40, pulse 120-130; temperature 102.8 per rectum. Normal resonance on percussion over the entire lung.

January 1, 1915.—Respirations 40, pulse 130, temperature 102. Tympanitic resonance over entire left chest with crackling of subcutaneous tissues upon palpation. Normal resonance over right lung.

January 2.—Respirations 40, pulse 132 and temperature 101.5°. The dog gradually improved, and recovered from the operation, became very active, and barked very loudly so that he could be heard all over the medical building.

June 12.—Six months after operation the dog weighs 30 pounds or 13-7/10 kilos. This loss of weight may have been due to the confinement in

CASE XVIII. Photomicrographs of sections of (13) unoperated lung, congestion, anthracosis, some alveoli overdistended; (14) operated lung, subacute purulent inflammation, organizing fibrino-purulent pleuritis; (15) operated lung, subacute purulent inflammation, organizing fibrino-purulent pleuritis; dense fibrous connective tissue covering lung tissue; (16) operated lung, *a*, atelectasis, *b*, collapsed bronchus, *c*, scar tissue following operation.



the laboratory without exercise out of doors. The food was not as nourishing in character during the last month as it was during the rest of the year. Dog was killed with ether. There were numerous adhesions between the operated lung and the chest wall, also marked anthracosis of both lungs. The fascia lata was united with the pleura covering the lung. No fluid in either pleural cavity. The pathologic report from Dr. Weller upon the lungs is as follows:

"Unoperated lung, marked anthracosis, some emphysema, otherwise practically negative. Site of operation: a subacute purulent inflammation. Small abscess. Healing progressing rapidly about the abscess."

CASE XVII. Operation: Resection of one lobe of left lung. Result: Recovery.

April 9, 1915.—Black and white male mongrel weighs 50 pounds. Number 24 French catheter passed into larynx and trachea after the dog was anesthetized. One rib resected subperiosteally. Pressure 25 to 30 millimeters. Resection of middle lobe of left lung, under the same aseptic precautions as are used in any major operation in a modern hospital. Several bronchioles ligated with silk and lung wounded sutured with mattress stitches of silk and a strip of fascia lata sutured over it. There was no leakage of air after the lung suturing was complete. External wound sutured in layers and sealed with gauze and collodion.

April 10.—Respirations 30, dog doing well.

June 12.—Two months after operation, dog weighs 32½ pounds or 14-7/10 kilos; looks emaciated probably because of poor food and confinement. Killed with ether. Some small adhesions between the operated lung and the chest wall and between neighboring lobes of the lung. Fascia lata united over the lung.

Pathologic report from Dr. Weller: "Unoperated lung: Practically normal. Some emphysematous areas. Seat of operation: Areas of atelectasis. Sutures still remain. No positive traces of fascia lata. Inflammatory process practically healed."

CASE XVIII. Operation: Resection of one lobe of left lung. Result: Recovery.

April 19, 1915.—Small female dog weighs 22½ pounds. Number 21 French catheter passed into the larynx and trachea after the dog was anesthetized. Aseptic operation performed by Drs. Hayes and Cattermole. Resection of one rib subperiosteally. One lobe of the lung was removed and wound carefully sutured after ligating the bronchioles and vessels. The lung wound was covered with a portion of the fascia lata. External wound closed and sealed with gauze and collodin.

April 20.—Dog doing well and shows no bad symptoms.

June 12, 1915.—Weight is 16½ pounds, or 7-3/10 kilos, emaciated in appearance, probably from confinement and inferior character of the food during the last month. Wound healed with very little scar tissue. Killed with ether and lungs removed.

Pathologic report Dr. Weller: "Unoperated lung; congestion, anthracosis, some alveoli appear over distended. Operated lung: Sub-acute purulent inflammation. Embedded sutures. Organizing fibrinopurulent pleuritis."

SUMMARY OF THE NINETEEN EXPERIMENTAL CASES.

Case I. Pneumectomy. Recovery.

Case II. Pneumectomy. Death, 5th day. Empyema.

Case III. Pneumectomy. Death, 2nd day. Pneumothorax.

Case IV. Pneumectomy. Death, 30th day. Empyema.

Case V. Pneumectomy. Death, 3rd day. Pneumothorax.

Case VI. Pneumectomy. Death, 6th day. Pneumothorax.

Case VII. Pneumectomy. Death, on table. Paralysis of Glottis.

Case VIII. Pneumectomy. Death, 2nd day. Pneumothorax.

Case IX. Pneumectomy. Death, 2nd day. Over-pressure.

Case X. Pneumectomy. Death, on table. Pneumothorax.

Case XI. Pneumectomy. Death, 7th day. Over-pressure empyema.

Case XII. Pneumectomy. Death, 2nd day. Over-pressure and distemper.

Case XIII. Pneumectomy. Death, 3rd day. Distemper.

Case XIV. Pneumectomy. Recovery.

Case XV. Pneumectomy. Death, 6th day. Empyema and distemper.

Case XVI. Application of insufflation. Recovery.

Case XVII. Pneumectomy. Recovery.

Case XVIII. Pneumectomy. Recovery.

Case XIX. Pneumectomy. Death, 4th day. Over-pressure and distemper.

There were eighteen lung operations and four recoveries.

RECOVERIES.

Many of these experiments were failures because it was necessary to develop the technic by careful experimentation before successful surgery upon the

lung could be done. An examination of these results will enable one to form an adequate idea of the difficulties that must be overcome in performing operations upon the lungs. As the majority of the dogs operated upon were afflicted with canine distemper the mortality is necessarily much higher than it would have been if healthy animals could have been obtained for this work. A careful study of these results warrants the following conclusions:

Intratracheal insufflation was not without harmful effects upon the lungs even in those dogs who recovered. Interstitial emphysema and over distension of some of the alveoli of the lung were shown microscopically. These changes were much more marked in those animals that died than in those that recovered and consisted of large hemorrhagic areas with tearing of the walls of the alveoli. Insufflation also has a very harmful effect upon the circulation in the lungs as is shown by the intense congestion and atelectasis found microscopically. In applying this method of anesthesia to intrathoracic operations upon the human being great care must be exercised in order to have the pressure high enough to prevent pneumothorax and still not so high as to cause serious damage to the circulation in the lungs or to cause a severe degree of interstitial emphysema.

The transplantation of a strip of fascia lata upon a wound of the lung gives an added protection to it from infection. Preliminary ligation of the bronchi and careful suture of the lung tissue must always be done. After the suturing is complete careful search must be made for the escape of air from the lung wound by moistening it with salt solution. If any air escapes the wound must be reenforced by additional suturing. For intratracheal insufflation a catheter of number 18 to 24 French should be used and the pressure should be maintained at 20 to 25 millimeters of mercury.

I desire to thank all those who assisted me in these experiments and especially Dr. Warthin for the examination of the pathologic material and the preparation of the photomicrographs which form a part of this article.

THE INTERSTATE ASSOCIATION OF ANESTHETISTS WILL MEET IN TOLEDO, OHIO, OCTOBER 9, 10, AND 11. THERE WILL BE A JOINT SESSION WITH THE MISSISSIPPI VALLEY MEDICAL ASSOCIATION AND A SPECIAL SECTION ON ANESTHESIA FOR ORAL SURGERY AND DENTISTRY.

THE NASAL ADMINISTRATION OF NITROUS OXID-OXYGEN ANESTHESIA UNDER LOW PRESSURE.*

M. ECKER, D.D.S.,
NEW YORK CITY.

It is not the purpose of this paper to trace the history of nitrous oxid as an anesthetic agent, nor to dwell upon the various theories concerning its action, as deduced from experimentation with lower animals. The parts played, in directing attention to this new use of *laughing gas*, by Dr. Colton, who, in 1867, reported 20,000 administrations of nitrous oxid, and by Dr. Wells, who foresaw the possibilities of this agent, are now matters of common knowledge.

It may be brought to mind, however, that these two pioneers employed nitrous oxid alone, thus inducing an asphyxial form of anesthesia. Dr. Andrews, in 1868, was one of the first to report the use of nitrous oxid in combination with oxygen, thus obtaining a non-asphyxial, and consequently a safer and more satisfactory form of anesthesia. With the addition of ether this form of anesthesia is now used in over 80 per cent. of all surgical operations, whereas nitrous oxid and oxygen is considered the ideal anesthetic in minor surgery.

DANGERS OF ADMINISTERING NITROUS OXID ALONE.

According to Gwathmy, experimental observations have established the fact that nitrous oxid, when given alone, induces asphyxia by the gradual paralysis of the respiratory center. In consequence of the prolonged action of the increasingly deoxygenated or venous blood, the respirations, at first rapid and deep, become convulsive as the process of deoxygenation is continued, then slow and shallow, finally ceasing altogether. Nitrous oxid, therefore, causes death by asphyxia.

With an increasing knowledge of the physiological action of the gas and with a clearer understanding of the dangers involved, the use of nitrous oxid alone has been practically abandoned. It is now generally employed in combination with air or oxygen.

ADVANTAGES OF ADMINISTERING NITROUS OXID WITH OXYGEN.

It has been found from experience, re-enforced by animal experimentation that certain advantages are derived from the administration of nitrous oxid with oxygen. These are:

(1) The anesthesia is non-asphyxial, safer, deeper, and more satisfactory in every way than when nitrous oxid is given alone.

* Read before the New Society of Anesthetists at the meeting of May 2, 1917, with cinematographic demonstration.

(2) The anesthesia can be maintained for an indefinite period of time, without danger to the patient, and without embarrassment to the operator, especially when a nasal inhaler is properly empoyed.

APPARATUS FOR ADMINISTERING NITROUS OXID WITH OXYGEN.

For short oral operations, such as the extraction of a single tooth, or the opening of an abscess, the face mask has its place; but for longer operations, such as the extraction of a number of teeth, or the handling of the various anomalies which the dental surgeon encounters, a nasal inhaler is now considered an absolute necessity. Considerable thought, therefore, has been devoted to the matter of devising an apparatus which meets all the requirements, not only with régard to the inhaler *per se*, but as to the apparatus as a whole. What are these requirements?

(1) There must be an absolutely regular flow of each gas, at any rate desired, without the necessity of frequent valve or stop-cock manipulation.

(2) The flow of gases must be rendered visible, so that these proportions may be approximately estimated at a glance.

(3) An efficient method must be available for adding ether vapor gradually, yet rapidly, up to any amount that even an extreme case may require.

(4) The nasal piece must be so modified as to be absolutely air-tight, and also practically self-retaining. Let us consider for a moment, each of these requirements.

First: *Regular Flow of Gases.* The percentage of oxygen need give the operator no concern. The patient is the guide. The proportion of oxygen has been estimated at anywhere from 5 to 10 per cent. Conditions must govern the increase or decrease of the gases. Once the rate of each is determined, the regular flow must be maintained. This is the crucial point.

To obtain an even flow of nitrous oxid and oxygen from the liquid form, where the larger cylinders, that is, those containing 1,280 gallons of nitrous oxid and 400 gallons of oxygen are used, automatic reducing valves are necessary. For general use, however, cylinders containing 250 gallons of nitrous oxid and 75 gallons of oxygen are more practical. These are attached directly to the apparatus, not requiring reducing valves.

Second: *Visible Control.* The apparatus must be so constructed as to render the rate of flow or percentage of the gases visible, so that the relative proportion of each gas may be estimated at a glance. This assures the operator that the flow is actually taking place. This has been solved by having each gas bubble pass separately through equal parts of glycerine and water, into a glass mixing chamber. The volume of gases delivered to the patient is controlled by a fine needle-valve adjustment, acting against the low pressure delivered by the reducing valve. The important factor is to determine the proportion of nitrous oxid and oxygen suitable to the individual patient. Practice is the only sure teacher and guide, but after several administrations, and by close observation, by being able to recognize the various symptoms, and by paying attention to the proper adjustment of the nasal inhaler, the valves can be so regulated as to maintain normally *pink* anesthesia.

Third: *Method of Adding Ether.* The ether attachment for our routine is seldom used. In extreme cases I occasionally give a little ether with the nitrous oxid and oxygen.

Fourth: *Air-tight Nasal Piece.* Some years ago Dr. Teter improved the technic of nasal anesthesia when he devised a method of using oxygen with warm nitrous oxid by means of his nasal inhaler. I have never seen a metallic or a rubber inhaler that could be considered universal, that is, one that could be adapted to fit any nose without a slight leakage of air, thereby failing to give a perfect anesthesia. I tried one of these metalic inhalers with an aperture and an extended rim, so that gauze could be packed in to fill out the various anatomical structures, thus fitting the various size noses with which I was confronted. I came to the conclusions that for perfect adaptation a nasal inhaler must be constructed of soft rubber. I therefore proceeded to devise the one which I shall present presently. It is absolutely air-tight, it is self-retaining, it can be used for an indefinite period, it can be boiled and sterilized, it costs very little, and it can readily be replaced.

I may call to mind, in this connection, the objectionable features of the exclusive use of the face-mask. They are apparent to all. The middle or index finger of the right hand must be held over the controlling valve, and the left hand over the nose and mouth of the patient to insure perfect adaptation. Very often, during anesthesia, the patient displaces the mouth-prop, rigidity sets in, and you have to wait until the anesthesia becomes shallow before you are able to force the jaws apart and to replace the prop. Now you either extract one or more teeth, or you again apply the inhaler and proceed to reanesthetize the patient. During the operation the mouth becomes filled with congested blood, the field of operation is obstructed, the patient becomes cyanotic; you endeavor the swab out the blood and saliva, and you try to remove the re-

maining teeth in a very short period of time. You invariably lacerate and do other uncalled-for injuries to the gums or other structures. No other thought enters the mind but to *get out the teeth.*

With nasal anesthesia, on the other hand, the inhaler being self-retained, both hands are free, you watch your patient, you see the prop, you can pack the throat with gauze, you can take your time; you can extract one tooth or more, and you can swab out the mouth or the sockets if necessary.

Now let us assume, that the respirations become shallow, the patient breathing through the mouth, or worse, holding his breath. This is a very important factor. In such event, stop the anesthesia,

Fig. 1. Placing the rubber ball of the Ecker Nasal Inhaler in position by adapting it to the bridge of the nose, then pressing it gently downward.

or lift the inhaler from the nose, for with the next inhalation the great pressure may cause muscular spasm, respiratory failure, and often serious results. If the patient struggles, or holds his breath, and then inspires deeply, the extra amount of gas brought to the heart suddenly may paralyze it. The danger of such an accumulation of gas at a time when it is not wanted, or when it would be risky for the patient, is practically impossible, with outfit presented.

Granting that the dentist who administers a general anesthetic, is able to recognize the symptoms of respiratory and cardiac failure; admitting that the best results are obtained when he is able to work with comfort and leisure; which means that he need not worry about the patient getting too much of the anesthetic or coming out of the anesthetic state before the work is done—what apparatus or combinations thereof, best meet these requirements?

It is my opinion that one of the principle reasons for my success is the low pressure with which the Gwathmey apparatus and my nasal inhaler permit me to work.

The opinion that nasal anesthesia with the mouth

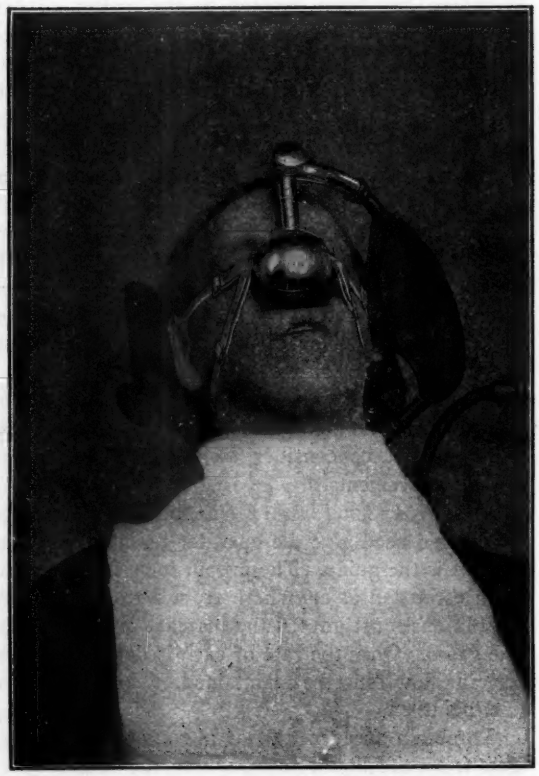


Fig. 2. Metal cover and breathing bag adapted to the rubber ball and strapped in position.

open requires high pressure, and with it large volumes of gas and oxygen, is quite prevalent. But I can say that I am doing under low pressure, and consequently with small amounts of gas, just as well, even better than I formerly did with high pressure. I believe that in this difference between the two methods may be found the clue to the solution of the technical problem, that is, a proof that it is not essential or right to us high pressure for nasal anesthesia.

From a series of tests with a mercury gauge attached on the gas outlet of the sight feed, that is, directly in the gas channel to the patient, the pressure used did not exceed 10 millimeters, and was, on the average, below 5 millimeters. I can furthermore state that the average of gas used is 2 to 4 gallons per minute. This is easily determined, since sight feed holes are of standard guage, and the amounts passing through each hole are steady, without fluctuations, if the gas valve is heated. I now average about 5 to 7 gallons of nitrous oxid to an administration. Formerly, with high pressure, I averaged 10 to 12 gallons of nitrous oxid to an administration.

Fig. 3. Side view of the inhaler in position.

Why is it that I succeed, with *small amounts of gases under low pressure,* rarely with forcing, in obtaining a perfect nasal anesthesia? And when I say perfect, I mean an anesthesia which enables me to extract, with the greatest ease, and without fear that the patient will come out too soon, a mouth full of teeth, if this is necessary. My answer is that, in working *without leak and with a minimum loss,* through the mouth, by using low pressure; I am giving the patient no more than he can take. In short, as I have said before, with my nasal inhaler the danger of accumulation of gas at a time when it is not wanted, and when it would be risky for the patient, is practically impossible.

DESCRIPTION OF THE ECKER NASAL INHALER.

The Ecker nasal inhaler consists of a spherical rubber piece, a round cap metal holder with hooks for attachment of straps; an angular or straight nose nipple, with an expiratory valve; a small breathing bag, and rubber tubing leading to the apparatus.

It is as simple and compact as possible, and offers, with its rounded symmetrical surface, absolutely no obstruction to the operator's hand.

In conjunction with an apparatus delivering the gases at low pressures this inhaler consumes extra-

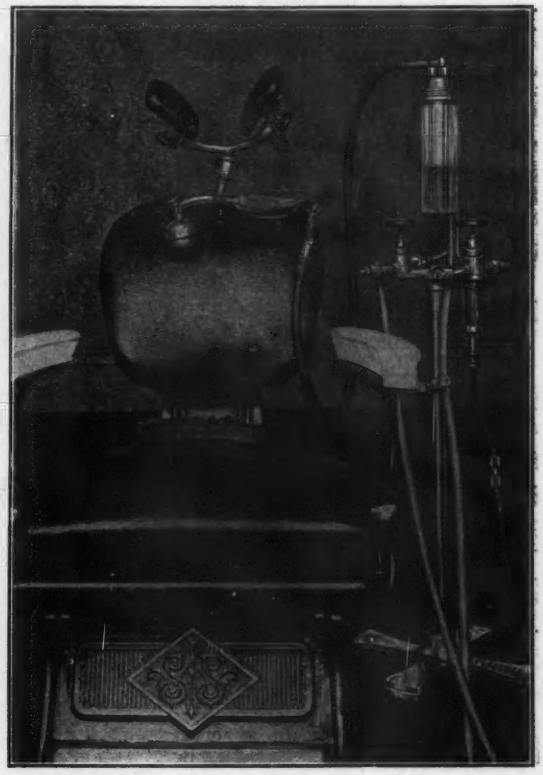


Fig. 4. Author's arrangement of apparatus and sight feed adapted for dental anesthesia and analgesia.

ordinary small quantities of the anesthetic and produces results.

From the foregoing description you will now understand that in order to prevent the accumulation of gas when the patient stops breathing, and, conversely, to prevent the onrush of too large a volume of the mixture when the patient starts to breathe, it is not necessary to remove the inhaler. The accumulation of gas in the small rubber tube amounts to nothing, and the contents of the little breathing bag can be pressed out with one hand in

one motion when the expiratory valve is open. If the occasion arises, I can shut off the gas-control valve, press out the mixture from the bag, and eventually let the oxygen run. A fresh supply of the mixture, whenever the time comes, is immediately obtained, eventually in different proportion with less nitrous oxid and more oxygen.

The smaller the amounts of gas and oxygen that you have to control, the better. Emptying the bag, refilling under different proportions, and setting a new mixture, is accomplished with this apparatus as quickly as it is spoken. The control is perfect.

I often get the patient under with gas only, or with a very small addition of oxygen. Whether I use gas through the fourth or fifth hole, or through the bottom of the tube, I will know immediately when watching the depth of the patient's rebreathing, as indicated by the small breathing bag. If I start with the fourth hole, and find that the patient empties the breathing bag, I go over to the fifth hole or to the bottom. *The rule should be that the breathing bag at the patient's expiration is nearly, but not quite, distended.* If the fourth hole keeps the bag nearly extended and the patient breathes normally, there is no reason to increase. On the other hand, if distension is full, and if the patient is a nose breather, it may be good to decrease the gas-flow to the third hole. whereby again you should consider that by such rebreathing there will be no carbon dioxid, consequently the patient will stand more oxygen without the risk of coming to.

The small breathing bag attached close to the nasal inhaler is a wonderful indicator of the patient's breathing. If you are able to draw conclusions from the character of the breathing you will be able to utilize the rythmic motions of the breathing bag as a guide for quickly obtaining and easily maintaining the proportions of the anesthetic mixture. I wish again to emphasize that this breathing bag and the visible gas flow through the sight feed place you in a position to master the situation from beginning to end.

In conclusion I desire to draw especial attention to the following points, observance of which will enable you to obtain a better and a safer anesthesia:

(1) Do not forget to use the rebreathing bag occasionally, for the rebreathing of the expired carbon dioxid acts as a respiratory stimulant.

(2) Do not cause much, if any, cyanosis in inducing anesthesia.

(3) Do not be in too great a hurry in bringing the patient under the influence of the anesthetic. Take your time, thus giving the system an opportunity to accustom itself to the anesthetic agents.

147 FOURTH AVE.

LARYNGECTOMY UNDER NERVE BLOCKING.*

MALCOLM L. HARRIS, M.D.,
CHICAGO, ILL.

The case which we wish to show this morning presents the following history, omitting unessential details: F. K., age forty-seven. He has been feeling poorly for the past six months, during which time he has complained of a sore throat, cough, and difficulty in swallowing. He has had a mucopurulent sputum, streaked with blood, which has become quite profuse of late. For the past month he has been unable to swallow without great pain, and about three weeks ago he lost his voice, so that now he can speak only in a whisper. His appetite is poor and he has vomited after eating several times recently. He says he has lost about 60 pounds in weight. His general appearance is bad, he is poorly nourished, shows a great loss of weight, and his muscles are flabby. The important part of the physical examination, so far as we are now concerned, relates to the larynx. This is found to be filled with a nodular ulcerated mass. The right vocal cord is entirely destroyed and the left one paralyzed. The mass so fills the larynx as to cause a marked stenosis. There are a few palpable, enlarged, hard lymph-glands on either side, particularly the left, in the upper anterior triangle of the neck.

A diagnosis of advanced carcinoma is unmistakable, but notwithstanding the advanced stage of the disease and the poor general condition of the patient, the stenosis is so marked and the dyspnea so intense that an operation is imperative in order that he may have relief. A simple tracheotomy would give relief so far as the dyspnea is concerned, but we feel that the patient should be given a chance at least for that greater relief which may come from a more radical operation, and this, too, in spite of the fact that a few of the neighboring lymph-glands are already involved. We are also led to the major rather than the minor operation for the further reason that a complete laryngectomy is but little more difficult than a proper tracheotomy. Exception may be taken to this last statement by many who have done laryngectomy by the older method with general anesthesia, and we will agree perfectly with anyone that a complete laryngectomy, done with all the annoyances, difficulties, and dangers of the usual general anesthesia, is a very trying as well as a serious operation, but under nerve blocking the

* From the Surgical Department of the Alexian Brothers Hospital, by courtesy of the Surgical Clinics of Chicago.

operation is robbed of most of its difficulties and becomes quite simple.

Under nerve blocking the operator is freed from the annoyances inevitably connected with the anesthetist and his apparatus, the tracheotomy tube, and other inconveniences, and can proceed with the operation with a perfectly free field. The nerve supply of the anterior region of the neck is well adapted to nerve blocking, and almost all operations involving this region can be performed by this method with great satisfaction. To block this region the needle is inserted just behind the middle of the posterior border of the sternomastoid muscle. The external jugular vein usually crosses this muscle at about that point, so that the needle usually enters just above and behind the point of crossing on the vein and the posterior border of the muscle, but the vein varies somewhat at times, so that it alone is not a reliable guide. The vein, however, should be identified before inserting the needle, so as not to puncture it and thus inject the solution into the vein. The point of the needle should lie just beneath the deep fascia in immediate proximity to the branches of the superficial cervical plexus. Solution used:

Novocain, ½ per cent.....3 parts
Calcium chlorid, 2 per cent.....1 part
Magnesium chlorid, 2 per cent...½ part

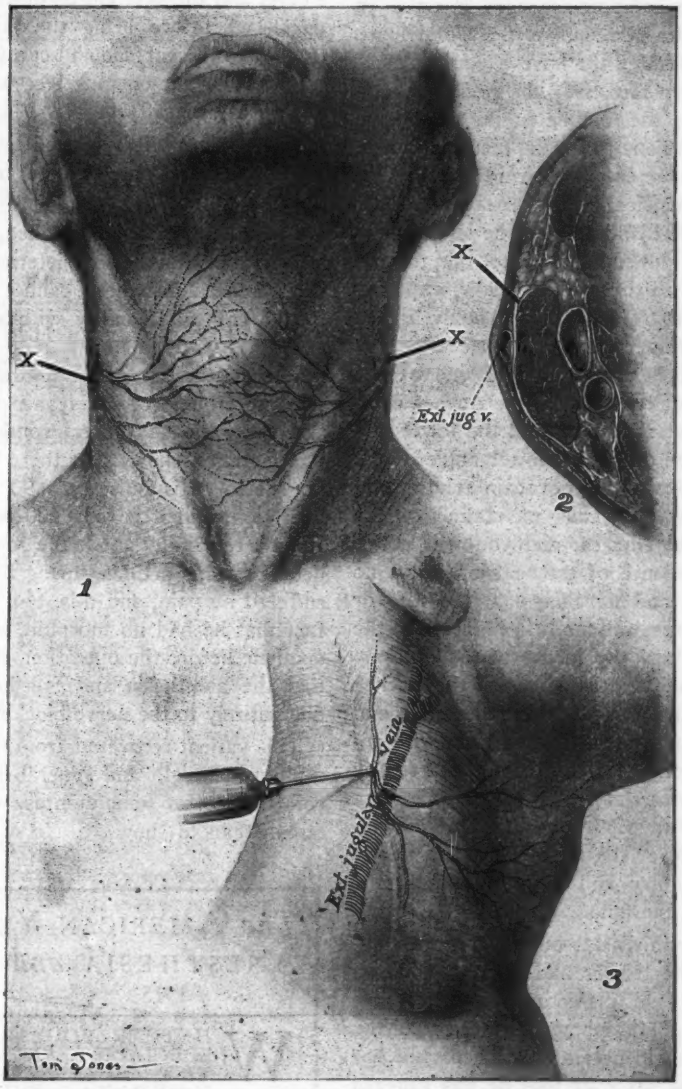


Fig. 1. 1 and 3 show the distribution of the nerve supply of the neck and the point at which the needle is inserted for the injection of the anesthetic. In 2 the position of the injecting needle and the anatomic relations are shown in cross-section. (Courtesy of W. B. Saunders Company).

Mixed at the time of using, and to which about 6 drops of 1:1000 adrenalin solution are added, just before using, to 60 c.c. of solution.

The needle being now inserted, as shown in figure 1, 25 c.c. of the novocain-calcium-magnesium solution are injected on either side of the neck; 10 c.c. of the same solution are next injected on either side, near the outer end of the hyoid bone. In less than five minutes we have a complete anesthesia of the entire region of the neck. An incision is made along the midline of the neck from just above the hyoid bone to the suprasternal notch, and, on account of the enlarged glands on the left side, a transverse incision is made near the upper end parallel with the hyoid bone. The longitudinal incision is carried down at once to the thyroid cartilage above and to the trachea below, exposing the isthmus of the thyroid, which is doubly ligated and divided and the lateral halves pushed aside. A loop of strong silk is passed around one of the cartilaginous rings of the trachea, the trachea completely divided above that ring, and the lower end of the trachea drawn out at the lower angle of the wound. A few drops of the novocain solution are now injected into the mucous membrane of the proximal end of the trachea, and you will notice that there is no evidence of tracheal irritation, no tendency to cough, and no change in the rate or character of the respirations after treating the trachea in this manner. By means of the silk loop about the ring of the trachea the end of the trachea can be easily drawn forward out of the lower end of the wound so there is no interference with respiration. The advantage of not being bothered by the anesthetist at this point of the operation is very apparent. On account of the dissection of the upper anterior triangle of the neck, which we intend to make, we turn down and out skin-flaps at the upper angle of the incision.

We now proceed to dissect out the larynx completely, including the tissues and lymph-glands on either side above. On dissecting posteriorly we reach the region of the esophagus and the pharynx, and up to now you will notice that the patient has given no evidence whatsoever that he has suffered the slightest pain, but on cutting the wall of the pharynx he moves his hand as an indication that it hurts. This we would expect, as we are now in a region not supplied by the cervical plexus, but by the glossopharyngeal nerve, so we will now inject a few drops of novocain solution along the wall of the pharynx so as to block this region. In doing this we should be careful not to block the pneumogastric nerves. Having made this injection, we proceed with the dissection, and the patient gives no further evidence of pain. The larynx is now completely removed, including the epiglottis and the surrounding tissues. Fortunately, we are able to close off the pharynx in front, which we do with catgut. A drain is placed in the upper end of the wound and the skin closed down through the lower angle, where we bring the proximal end of the trachea to the surface and carefully suture it to the skin, leaving the opening free without the introduction of a tracheal tube.

The patient will be placed in bed and allowed to sit up at once, and will be fed for a few days through a tube.

Anyone who has undertaken, or even witnessed, an operation for the complete removal of the larynx under general anesthesia cannot fail to be impressed by the ease and facility with which the operation can be performed under nerve blocking. As you have seen, there has been no difficulty with respiration, no trouble or annoyance with the anesthetic, and the patient's general condition at the end of the operation shows that there has been practically no shock. His pulse was 90 before starting the operation, and it is only 100 now, the quality and fulness remaining about the same. It is quite evident from his actions during the operation that he suffered no pain, and this, too, notwithstanding the fact that he had no morphin, scopolamin, or other anodyne before the operation, showing conclusively that the anesthesia and freedom from pain were due entirely to the nerve blocking.

This patient recovered from the operation, gained rapidly in weight and general health, and was very comfortable for some months, when internal metastases began to show.

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F. HOEFFER McMECHAN, A.M., M.D., *Editor*
Avon Lake, Ohio, U.S.A.

JULY EDITORIALS. 1917

THE CALL TO THE COLORS.

Service in the field, in the base hospitals and with the Red Cross is no novelty to the anesthetists of the United States. Since the very beginning of the world war, many members of the various associations of anesthetists have been to the front, and now that the President has issued his call to the colors, there is no doubt that all anesthetists capable of so doing, will respond with alacrity.

To those whose one aim in their professional life is the alleviation of pain, neither the call of duty nor patriotism is necessary. Sufficient for them is the fact that their service is needed in the shambles of mercy behind the far-flung battle lines.

It is gruesome to know that the sheer lack of anesthetic drugs is compelling many surgeons to operate without the beneficence of anesthesia, especially in the field hospitals, and those, who on account of age or incapacity, must remain at home, should see to it that they and their friends provide the Red Cross with sufficient supplies of anesthetics to meet the existing demand.—McM.

THE NURSE ANESTHETIST DECISION IN KENTUCKY REVERSED.

As the Supplement goes to press comes the announcement that the Court of Appeals has reversed the decision in the nurse anesthetist case, rendered recently by Judge Kirby in the Circuit Court.

This reversal initiates a very deplorable situation with regard to the legal control of the practice of medicine in Kentucky, a state, which heretofore has been renowned for the protection it accorded its people in this respect. Undoubtedly the Kentucky State Medical Association, which declared the nurse anesthetist unethical and a menace to public safety, will see to it that the state legislature passes remedial legislation at the earliest possible moment.

Those who are proponents of the nurse anesthetist have the questionable consolation of knowing that while slavery has been abolished in the United States, they are attempting to initiate sweatshop conditions in the operating room. In this connection Amy Armour Smith, R.N., Superintendent of Nurses at the Woman's Hospital of the State of New York, in her recent volume, "The Operating Room," says: "A corporation should not make an ill-proportioned profit out of the services of any skilled employee. If a nurse anesthetist gives ten anesthetics per day at $10 each and receives a salary of $60 per month, she is exploited like a slave, and, worse still, she helps the system along."

It is interesting to note that the English Government in plunging women into the production of war munitions, did not have the temerity to exploit their labor, but has paid them the same salaries as men for similar work. This lesson in political economy should teach a striking lesson to those who are willing to betray the members of their own profession by underselling their expert service by exploited nurse anesthetists.—McM.

1917—MEETINGS—1917.

The Fifth Annual Meeting of the American Association of Anesthetists, held in New York City recently in conjunction with that of the A. M. A., was a success in every sense of the word. The papers of the scientific sessions were replete with experimental and clinical researches and the clinics held for the benefit of those in attendance, at the various New York and Brooklyn hospitals, demonstrated all the routine as well as the more advanced methods of anesthesia and analgesia. The Joint-Session with the A. M. A. Sections on Physio-Pathology and General and Abdominal Surgery went far to cement cordial relations and establish the conviction that anesthesia and the anesthetist deserve a more conspicuous part in the curriculum and clinic.

The Interstate Association of Anesthetists, despite war conditions, will hold its Third Annual Meeting in Toledo, O., October 9, 10 and 11, in conjunction with the Mississippi Valley Medical Association. An interesting and instructive program has been arranged. There will be a Joint-Session with the Mississippi Valley Medical Association as well as a Special Section of Anesthesia for Oral Surgery and Dentistry.

This will be one of the most important meetings in the Middle West this year and all those interested are cordially invited to attend.—McM.

Newer Apparatus

Editor's Note: From time to time this Department will publish Illustrations and Technical Details of the Newer Apparatus for Anesthesia and Analgesia.

THE PNEUMATIC INJECTOR: A SUBSTITUTE FOR LOCAL ANESTHESIA SYRINGES.

R. E. FARR, M.D.
Minneapolis, Minn.

The pneumatic injector is designed to replace the syringe in making infiltrations for local anesthesia. In order to compete with general anesthesia, local anesthesia must be administered with greater speed and less labor than has been possible heretofore with the ordinary equipment. The elements of time and labor necessarily expended have heretofore deterred surgeons in many instances from employing local anesthesia, thus denying patients the great advantages of this excellent method of anesthesia. The pneumatic injector furnishes the surgeon an unlimited amount of the solution, a steady flow under constant pressure, and makes it possible to administer this anesthetic in the minimum time with the minimum output of labor. The constant flow under measured pressure gives one a uniform, even infiltration of the tissues, thus saturating them without tearing them apart as is often the case with a *jerky* syringe, and that most syringes are *jerky* all will agree.

Anyone who has had much experience in the use of local anesthesia knows that the shortcomings of syringes are manifold. They are difficult to keep in order, easily broken, if large, they are difficult to manipulate; if small, they must be refilled innumerable times in doing a major operation, this work often requiring the services of one or more extra nurses. Unless carefully constructed and kept perfectly clean, the pistons do not glide smoothly and do not allow the uniform infiltration of the tissues so essential to perfect anesthesia without trauma to the tissues. The introduction of any considerable amount of fluid is slow and exceedingly irksome to the surgeon. The time required by the operating room staff in sterilizing and assembling syringes, and in dissembling, cleansing and drying them after an operation is considerable when much local work is done. The multiplicity of syringes on the market is sufficient evidence that none is satisfactory. If much local anesthesia work is done, the item of expense on account of breakage is important.

The pneumatic injector (Fig. 1) consists of the following parts:

(A) A Prest-O-Lite tank such as is used for inflating automobile tires. The tap for this tank fits into the socket. (B) which is also designed to fit the tap of an ordinary oxygen tank. (An air pump may be used for this purpose.) (C) is a cotton filter. (D) is a safety valve. (E) is a pressure gauge. (F) is a wing nut which marks the point where the glass cylinders are detached from the filter tube. This wing-nut can be loosened and tightened by hand, thus obviating the necessity of special wrenches. (G) represents the removable tops or covers of the glass cylinders. (H) Eccentric levers by which the tops are securely closed. (I) is an exhaust valve, one of which is placed at the top of each cylinder. Through these the pressure may be reduced before opening the top for any purpose. (J) indicates the glass cylinders which are graduated into ounces and one-fourth ounces. The cylinders are marked *N* and *Q*, respectively, to represent Novocain and Quinin. The glass cylinders are one-fourth inch thick and are specially constructed to withstand pressure. (K) represents the valve through which the cylinders may be drained. (L) represents the valves through which the fluid passes to the tubing. The valves are so arranged that a solution may be directed from either of the glass cylinders through either of the flexible metal tubes, or both of them at the same time. The direction in which the valve is turned indicates the direction in which the fluid will flow. (M) represents the flexible metal tubing through which the fluid passes to the cut-off to which the needle is attached. (N) is the cut-off. It is equipped with a ball-and-socket joint and will accommodate either a screw or a record needle. The ball-and-socket joint allows one to turn the needle in any desired direction. The telescopic rod upon which the cut-off and flexible metal tubing are hung is removed at the end of each operation and resterilized with the tubing and cut-offs.

In order to sterilize the glass cylinders they may be detached at the point *F* and boiled or autoclaved. The cross bar *C* is a tube which is converted into a filter by lightly packing with absorbent cotton (Fig. 2). After sterilizing the cylinders they are attached to the filter by a wing-nut (Fig. 3). We formerly used a compressed air tank, which is exceedingly handy, but at the present time an ordinary pump (Fig. 4) is used as we consider it safer. When all joints are properly tightened, the pressure is maintained for a considerable length of time. The glass cylinders are filled through a sterile funnel (Fig. 5), the adrenalin solution having been previously added to the anesthesia solution which insures a good admixture of the adrenalin and the novocain. An exhaust valve has been placed at the top of each cylinder so that the pressure may be released before raising the covers. Provided cold solutions are not poured into the cylinders when cylinders are hot, there is no danger of breaking them. Once the cylinders are sterile they will, of course, remain sterile for a long time. After the first sterilization by boiling, they may be sterilized chemically from time to time if one so

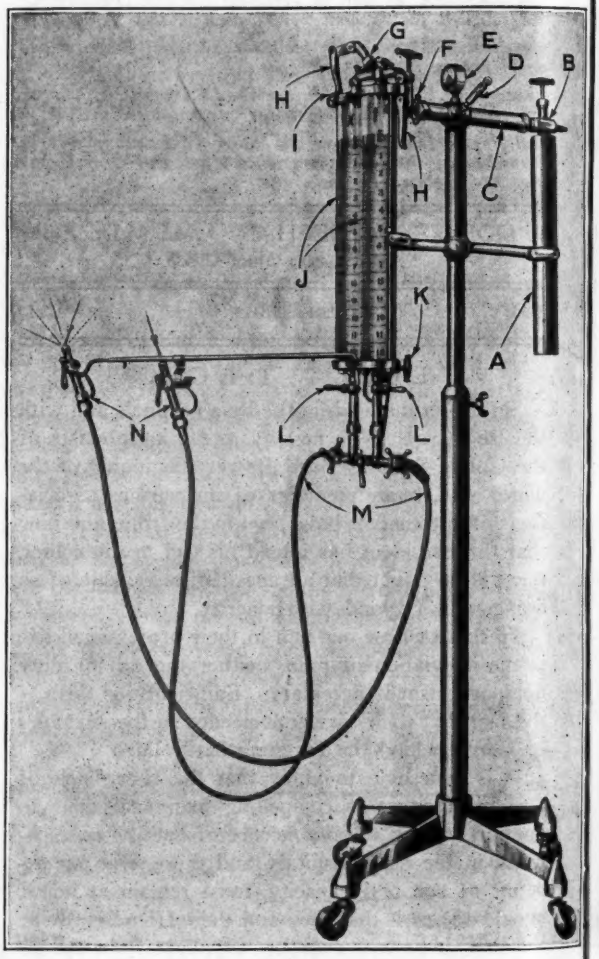
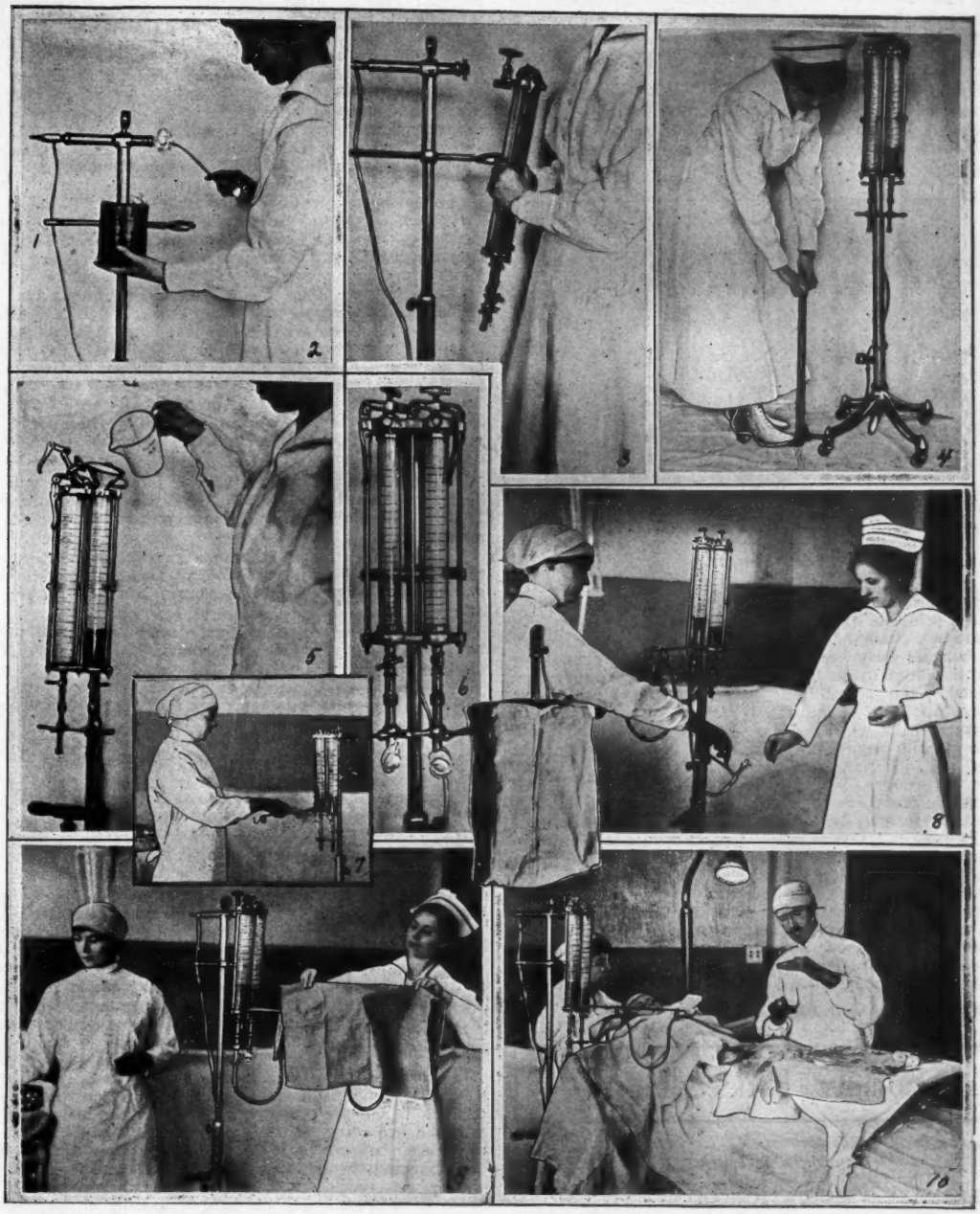


Fig. 1.

dentires. With the instrument covered (Fig 6) the solutions may be allowed to remain in the cylinders for a considerable length of time. For each operation the preparation consists of sterilizing the metal arm (Fig. 7) and the flexible tubing and cut-off with the instruments. After operation, a sterile drape may be thrown over the flexible tubing (Fig. 9). The anesthetist now arranges the valves *L* so as to direct the fluid through the tubing. While being *set up* the apparatus stands near the instrument table. After the draping of the patient the anesthetist moves the

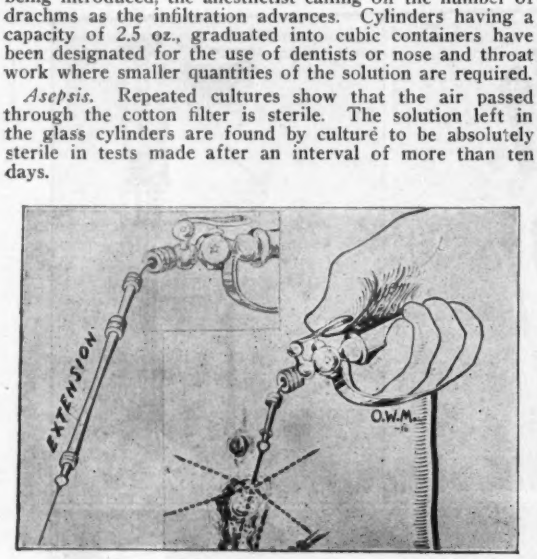


Figures 2 to 10.

scrubbing up, the instrument nurse places the metal support (Fig. 8) in its socket. She then takes the coiled flexible metal tubing in one hand and with a long artery forceps in the other hand passes this tubing to the anesthetist who attaches it to the apparatus by means of a wing nut (Fig. 8). If much time is to elapse between the setting-up of the apparatus and the performance of the apparatus into a convenient position. The entire extent of the surgeon's labor consists in allowing the air to escape from the tubing. When bubbles cease to come, the needle is attached to the cut-off and the injection proceeds (Fig. 10). The cut-off is equipped with a universal thread so that *screw* or *record* needles may be used. The ball-and-socket joint allows the needle to be directed as one de-

sires (Fig. 11). With the extension (Fig. 12) deep cavities may be supplied without any obstruction to the view. The cylinders have a capacity of from 10 to 16 ounces and are graduated in ounces and one-fourth ounces. One may therefore appreciate the rate at which the anesthetic is being introduced, the anesthetist calling off the number of drachms as the infiltration advances. Cylinders having a capacity of 2.5 oz., graduated into cubic containers have been designated for the use of dentists or nose and throat work where smaller quantities of the solution are required.

Asepsis. Repeated cultures show that the air passed through the cotton filter is sterile. The solution left in the glass cylinders are found by culture to be absolutely sterile in tests made after an interval of more than ten days.



Figs. 11 and 12.

An experience of five years with various models shows that the principle of the pneumatic injector is correct. In the author's clinic the apparatus has proved so satisfactory that syringes have been discarded entirely. Frequent inquiry has been made concerning the amount of pressure required. Naturally, this depends upon the nature of the tissue which is to be infiltrated, the size of the needle and the speed with which one desires to work. The loose tissues usually require not more than 20 pounds while scar tissue and such tissues as the uterine cervix may require 50 or 60 pounds. With moderate pressure and a rather fine needle the point of which is kept constantly moving, the anesthesia may be administered in less than five minutes in practically every case. As an adjunct to the armamentarium of the operating room, this apparatus has given great satisfaction aside from its use in the administration of local anesthesia. The injection of formalin-glycerin or other solutions where great pressure is required is made with the utmost ease. As an irrigator as well as in the introduction of hypodermoclysis one has always a sterile graduated pair of glass cylinders ready for any use for which they may be required.

PHYSICIANS AND SURGEONS BLDG.

Society Proceedings.

Membership in a society devoted to your specialty is an essential to success.

INTERSTATE ASSOCIATION OF ANESTHETISTS.

The Interstate Association of Anesthetists will hold its Third Annual Meeting in Toledo, Ohio, October 9, 10 and 11, 1917. This meeting will be in conjunction with that of the Mississippi Valley Medical Association, and a Joint-Session will be held. There will also be a Special Section on Anesthesia for Oral Surgery and Dentistry.

Among the papers and essayists on the program for this meeting may be mentioned the following: Methods of Teaching the Pharmacology of Anesthetics, Dennis E. Jackson, St. Louis; The Cytologic Analysis of Shock, D. H. Dolley, Columbia, Mo.; Further Researches in Blood Changes under Nitrous Oxid-Oxygen Anesthesia, Theodore D. Castro, Philadelphia; Liquid Air and Electrolytic Oxygen for Anesthetic Purposes, C. C. McLean, Dayton, O.; The Perfected Drop Method of Etherization and its Availability for Routine Surgery, Isabella C. Herb, Chicago; Ether and Etherization in Relation to Infections and Immunity, W. D. Haines, Cincinnati, O.; Nitrous Oxid-Oxygen Anesthesia and Analgesia in Obstetrics, C. E. Turner and W. I. Jones, Columbus, O.; Some Observations on Local Anesthesia for Certain Operative Procedures, Leigh F. Watson, Chicago, Ills.; Anesthesia for and the Technic of Direct Bronchoscopy, R. H. Johnston, Baltimore; Methods of Local and Conductive Anesthesia for Oral Surgery, Arthur E. Smith, Chicago; High Pressure Anesthesia for Cavity Preparation, W. T. Jackman, Cleveland, O.; Vapor Anesthesia for Oral Surgery, Joseph C. Beck, Chicago; Low Pressure Nitrous Oxid-Oxygen Anesthesia by Nasal Administration, M. Ecker, New York City; Anesthesia from the Surgeon's Viewpoint, F. G. DuBose, Selma, Ala.; Postoperative Pneumonia and its Relation to Anesthesia and other Causes, E. I. McKesson, Toledo, O.; Comparative Dangers and Availability of Nitrous Oxid-Oxygen Anesthesia, J. R. McCurday, Pittsburgh, Pa.; Vapor Anesthesia with Special Reference to the Use of Ether-Oxygen, Oral Administration, John J. Buettner, Syracuse, N. Y.; Anesthesia in the Surgery of Epileptics and the Treatment of Status Epilepticus, G. Kirby Collier, Sonyea, N. Y.; Some Observations on Postoperative Nephritis, Karl R. Ruddell, Indianapolis.

The sessions and exhibits of the Joint-Meeting will all be held in the Hotel Secor, as well as the Organization Dinner. The ladies in attendance will be entertained especially.

This will be one of the most important meetings in the Middle West this year and all surgeons, anesthetists and dentists who are interested are cordially invited to attend.

For further information, dinner reservations and membership apply to F. H. McMechan, M.D., Avon Lake, O., Secretary.

PROVIDENCE, R. I., SOCIETY OF ANESTHETISTS.

The annual meeting of the Providence, R. I., Society of Anesthetists was held in the New Medical Society Building on the evening of March 31, 1917.

Preceding the meeting, Dr. Paulel J. Flagg of New York City, the essayist of the occasion, was entertained at dinner by members of the society at the University Club.

During the meeting Dr. Flagg read a very interesting paper on "Intratracheal Insufflation Anesthesia."

After detailing the underlying physiological considerations connected with this method of anesthesia Dr. Flagg described the various phases of the technic of administration, especially the use of the Jackson laryngoscope for introducing the catheter and the advantages of the anesthetometer in providing an accurate, constant and tension-regulated flow of ether-vapor. Dr. Flagg emphasized the necessity of deep preliminary narcosis before attempting intubation, in order to avoid reflex spasm of the glottis and larynx. Complete extension of the head and direct vision of the glottis also facilitate intubation. Ordinarily a No. 24 French, silk woven urethral catheter with a side opening is the preferable one, although the size must be modified according to the individual. It should never be introduced beyond its 26 cm. mark and after introduction and touching the bifiurcation of the trachea, it should be withdrawn about an inch. A hissing of the return flow of air is an indication that the tube is actually in the trachea and that it has not been inadvertently introduced into the esophagus.

Dr. Flagg considered a pressure of between 18-20 mm. of Hg. sufficient for all purposes, and preferred to have the pressure readable on a Hg. manometer rather than controlled by an automatic blow-off set for a fixed pressure.

To aid diffusion of the anesthetic vapor and facilitate respiratory movements of the lungs, the intratracheal tube is pinched two or four times a minute, while the reaction

of the patient is carefully noted. Intratracheal insufflation obviates obstruction to respiration and delivers a constant vapor of sufficient concentration in a volume equal to all the respiratory needs of the patient. Acapnia may result from over-ventilation and is apt to occur following the withdrawal of the tube. After sickness is the exception and irritation of the vocal cords from friction of the tube seldom is noted.

The insufflation technic is indicated in all operations requiring the prevention of pneumo-thorax, and it has many advantages in all operations on the tongue, jaw, neck, trachea, larynx and the air passages or esophagus. It will also prevent suffocation from vomitus in intestinal obstructions.

Dr. Flagg's paper was discussed by several of the members.

The election resulted in the selection of Dr. Charles O. Cooke as President and Dr. E. S. Cameron as Secretary for the ensuing year.

E. S. CAMERON, M. D., *Secretary.*
223 Congress Ave., Providence, R. I.

Book Reviews

A carefully selected library is essential to a thorough knowledge of the science and practice of a specialty.

Experimental Pharmacology. By DENNIS E. JACKSON, PH.D., M.D., Associate Professor of Pharmacology, Washington University Medical School, St. Louis. Octavo, pp. 536, with 390 Original Illustrations, including 24 full-page Color Plates. C. V. MOSBY COMPANY, St. Louis, 1917.

The dearth of laboratory manuals giving exact, specific, detailed directions for carrying out most of the experiments which the student will be called upon to perform in the study of pharmacology, has led Jackson to prepare and publish his *Experimental Pharmacology.* This volume is of especial interest and importance to specialist in anesthesia, particularly those who are teaching the subject, since it deals with those drugs and anesthetic agents which are routinely employed by the anesthetist.

The experimental pharamcologic studies of ether, chloroform, nitrous oxid, ethyl chlorid and bromid, cocain, novocain, chloral hydrate, morphin, atropin, pituitrin, and other pertinent drugs are exhaustively detailed, and every step in the mechanism of experimentation precisely and fully illustrated.

The anesthetist who will master the experimental pharmacology indicated in this volume so that he can utilize it in teaching his classes in anesthesia, will find himself just that more of an accomplished expert and his teaching will redound to the benefit of the specialty he is pursuing. The volume attempts to inculcate the scientific spirit of research, so vital an incentive to success both in the teacher and student.

Jackson is to be congratulated not only on his interesting and instructive book, but also on his personal researches in the pharmacology of anesthesia, some of which are printed in this issue of the SUPPLEMENT.

The Surgical Clinics of Chicago. Volume 1, No. 2, April, 1917. Octavo, pp. 223-448, with 99 illustrations, Paper Covers. Published Bi-Monthly. W. B. SAUNDERS COMPANY, Philadelphia.

This issue of the Clinics sustains the high standards of interest set in previous issues. The work of such important clinicians as Andrews, Beck, Bevan, Davis, Dyas, Eisendrath, Halstead, Harris, Kanavel, Ochsner, and Percy are included.

The publishers have announced the merging of the *Murphy Clinics* and the *Chicago Clinics* into a new publication that will be entitled *The Surgical Clinics of North America.* It will be issued quarterly, and will be devoted to the publication of the advanced medical and surgical progress in the clinics of New York, Philadelphia, Baltimore and Chicago. This enlarged scope should make the new *Clinics* all the more attractive to those subscribers who have found the others invaluable.

Quarterly Index

Of the Current Literature of Anesthesia and Analgesia.

ACIDOSIS, INFLUENCE OF ON SURGICAL PROCEDURES. W. A. Lincoln, Calgary Alberta. Annals of Surgery, February, 1917.

ANESTHESIA ACIDOSIS, THE PROPHYLAXIS OF. Wm. H. Morris, New Haven, Conn. Journal of the American Medical Association, May 12, 1917.

ANESTHESIA, EVOLUTION OF. W. H. Dodge, Hancock, Mich. Michigan State Medical Society Journal, April, 1917.

ANESTHESIA AND ANALGESIA, HANDLING EMERGENCIES UNDER. N. T. Yager, Louisville, Ky. Dental Summary, April, 1917.

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—*Editor.*